Research Article

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# Hiatus resolution and linguistic diversity in Australian English

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**Abstract:** Vowel hiatus is typically resolved in Australian English through complementary strategies of liaison (j-gliding/w-gliding/linking-r) and glottalisation. Previous work suggests a change in progress towards increased use of glottalisation as an optimal hiatus-breaker, which creates syntagmatic contrast between adjacent vowels, particularly when the right-edge vowel is strong (i.e. at the foot boundary). Liaison continues to be used when right-edge vowels are weak, but glottalisation as a hiatus resolution strategy in general appears to be increasing and may be more common in speakers from non-English speaking backgrounds raising the question of whether exposure to linguistic diversity could be driving the change. We examine hiatus resolution in speakers from neighbourhoods that vary according to levels of language diversity. We elicited gliding and linking-r hiatus contexts to determine how prosodic strength of flanking vowels and speakers' exposure to linguistic diversity affect hiatus resolution. Results confirm that glottalisation occurs most frequently with strong right-edge vowels, and gliding/linking-r are more likely with weak right-edge vowels. However, strategies differ between gliding and linking-r contexts, suggesting differing implementation mechanisms. In addition, speakers from ethnolinguistically diverse areas produce increased glottalisation in all contexts supporting the idea that change to the hiatus resolution system may be driven by language contact.

**Keywords:** hiatus resolution; Australian English; glottalisation; linguistic diversity; prosodic strength

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# 1 Introduction

Vowel hiatus is a phenomenon in which a sequence of two heterosyllabic vowels occurs without an intervening consonant. In English, potential hiatus contexts can occur both within words and across word boundaries (*chaos* /kæɪ.ɔs/, *no answer* /nəʉ ænsə/).[1] The focus of this paper is hiatus that occurs across word boundaries. Cross-linguistically, it has been suggested that roughly half of all languages disallow hiatus (Bell and Hooper 1978). This is likely because hiatus is phonologically undesirable as it reduces the syntagmatic separation between syllables. In English, a range of strategies may be employed to resolve hiatus. Allerton (2000), for example, suggests five such strategies used to manage V#V hiatus sequences:

(1) (true) hiatus, in which the adjacent vowels are produced without any form of hiatus resolution, resulting in two adjacent sonority peaks which may reduce the clarity of the syllable boundary;
(2) elision, in which one of the vowels (often a weak vowel) is not produced;
(3) liaison, where an intervening linking consonant is inserted/emerges;
(4) diphthongisation/long vowel, in which the two vowels are produced as a single vowel/syllable;
(5) glottal stop insertion, in which the adjacent vowels are separated by an intervening glottal stop.

Other sources provide a similar suite of strategies, albeit with some minor variations in terminology and categories (e.g. Broadbent 1991; Casali 2011). Much of the previous work on hiatus resolution in English has focussed on the third and fifth of these strategies: liaison and glottal stop insertion; although, as we shall see, true hiatus and elision may also be employed in some cases.

Typically, liaison in English refers to the emergence of one of the approximants [j, w, ɹ][2] between the two adjacent vowels, with the consonant that surfaces being phonologically conditioned by the features of $V_1$ in the $V_1\#V_2$ sequence: [j] surfaces following front high vowels; [w] surfaces following non-front high vowels; and, in many non-rhotic varieties such as Australian English (AusE) (the variety examined in this paper), [ɹ] surfaces following non-high vowels (Allerton 2000; Broadbent 1991; Casali 2011; Cox et al. 2014; Hay et al. 2018; Hay and Sudbury 2005). In the case of [ɹ] liaison (also referred to as r-sandhi), a further distinction is often made between linking-r and intrusive-r, with linking-r occurring when the hiatus breaking rhotic is

1 We use the symbols recommended in Harrington et al. (1997) and Cox and Palethorpe (2007) for transcribing Australian English phonemes, the target variety of English examined in this paper.

2 Liaison involving the lateral approximant [l] also occurs in some dialects of American English, where it patterns similarly to intrusive-r, albeit less frequently (Gick 1999, 2002).

represented in the orthography (e.g. *four o'clock* [foːɹəklɔk]) and intrusive-r occurring when there is no orthographic rhotic (e.g. *saw a clock* [soːɹəklɔk]) (Broadbent 1991; Foulkes 1997; Gick 1999; Hay and Maclagan 2010, 2012; Hay et al. 2018; Pavlik 2016; Tuinman et al. 2011; Yuen et al. 2018). Some studies have identified differences between the rates at which linking-r and intrusive-r surface, with linking-r occurring more frequently (e.g. Hay et al. 2018; Hay and Maclagan 2010, 2012; Hay and Sudbury 2005; Mompean 2022; Mompeán-Gonzalez and Mompeán-Guillamón 2009). However, Hay et al. (2018) found for New Zealand English that rates of linking and intrusive-r were similar in the speech of their younger participants compared to previous historical analyses showing greater incidence of linking-r (Hay and Maclagan 2010, 2012; Hay and Sudbury 2005). In studies of AusE speaking children (Yuen et al. 2017) and adults (Yuen et al. 2018), no differences were found in the incidence of r-sandhi across linking and intrusive contexts suggesting that similar processes are involved in each. In this paper, our analyses focus on various linking contexts, including but not limited to linking-r, but we do not investigate intrusive-r.

Although the approximants that surface when hiatus is resolved by the liaison strategy are sometimes referred to as inserted or epenthesised, it is not clear whether segment insertion occurs or whether the percept of a segment results from listeners' interpretation of the vowel to vowel transition as segmental. One suggestion regarding the glides [j, w] is that these surface due to phonetic effects rather than through a phonological epenthetic process (Blevins 2008; Davidson and Erker 2014; Heselwood 2006); that is, the percept of a homorganic glide between two adjacent vowels may simply arise as a result of the articulatory transition (interpolation) from one vowel in the sequence to the next, with the 'inserted' consonant being epiphenomenal. Some authors illustrate the difference between transitional glides and segmental glides through the use of superscript symbols for transitional glides (e.g. Cruttenden 2008; Heselwood 2006). Blevins (2008) suggests that the percept of the glides [j] and [w] arises through a segmental reinterpretation of formant transitions across the hiatus. This reinterpretation occurs because the transitions resemble contrastive glides in the phonology of the language. Davidson and Erker (2014) support an interpolation explanation based on findings from American English (AmE) showing that glides occurring at word boundary hiatus contexts differ in terms of duration, intensity, and formant frequency values when compared to lexical onset [j, w] glides with the same surrounding vowel environments. Davidson and Erker (2014) did not examine r-sandhi contexts and state that more work is needed to understand the relationship between hiatus resolution through gliding versus r-sandhi.

Whether or not hiatus-resolving [j] and [w] glides are inserted or epiphenomenal has not been tested in the context of AusE, but there is evidence that r-sandhi cannot simply be the result of a phonetic articulatory transition. Yuen et al. (2018) found that

AusE speakers produced anticipatory coarticulation in the form of lowered F3 during the early part of the $V_1$ in both hiatus contexts resolved by r-sandhi (e.g. *floor of)* and in contexts that included lexical /ɹ/ (e.g. *forest*). They interpret this finding as evidence for the rhotic being planned in advance, which would be at odds with a passive phonetic transition, and hence they suggest a phonological role in the process. Few studies have examined a set of hiatus contexts that would potentially elicit all three approximant insertion types ([j, w, ɹ]). The present study addresses this gap in the literature.

In addition to liaison, another hiatus resolution strategy that has received attention is glottalisation. In some cases, this is referred to as (complete) glottal stop insertion, but it is also often reported as a period of glottalised/laryngealised phonation, which might be considered as an incomplete glottal stop or glottal constriction occurring at the hiatus juncture (Allerton 2000; Blevins 2008; Davidson and Erker 2014; Foulkes 1997; Mompean 2022; Mompeán and Gómez 2011; Pierrehumbert 1995). In a study of r-sandhi contexts in the speech of RP speaking BBC newsreaders, Mompeán and Gómez (2011) found that 31 % of items were produced with glottalisation. Similarly, in their study of AmE that examined elicited potential gliding contexts only, Davidson and Erker (2014) found that hiatus at a word boundary was resolved with glottalisation in 45 % of items. In AusE, Cox et al. (2014) found glottalisation was used to resolve hiatus at word boundaries in 23 % of items in linking-r contexts elicited in a sentence reading task.

The use of glottalisation versus linking consonants is conditioned by the strength of the prosodic boundary between the two vowels: when $V_2$ is strong,[3] that is, when there is a foot boundary between $V_1$ and $V_2$, glottalisation is more likely to surface, and when $V_2$ is weak, and hence no foot boundary is present, a linking consonant is more likely (Cox et al. 2014; Foulkes 1997; Mompean 2022; Mompeán and Gómez 2011; Yuen et al. 2018). For example, for linking-r contexts in AusE, Cox et al. (2014) identified glottalisation in 51 % of items with a weak $V_1$ and strong $V_2$ (WS), compared to only 14 % when $V_1$ was strong and $V_2$ weak (SW) and 22 % when both vowels were weak (WW), with the remaining items realised with linking-r. In a subsequent study of r-sandhi in AusE, Yuen et al. (2018) also showed complementarity between glottalisation and r-sandhi with glottalisation more frequent (and r-sandhi less frequent) before a strong $V_2$, and less frequent (with r-sandhi more frequent) before a weak $V_2$. They also showed that the distance separating the hiatus from the foot boundary influenced whether glottalisation or rather r-sandhi surfaces in hiatus: items in which the foot boundary was directly to the right of the weak $V_2$ (e.g. | *paw a|bove*; SW) were more likely to exhibit glottalisation than those further removed from the

3 In this paper, strong vowels refer to vowels in prosodically stressed syllables, and weak vowels refer to vowels in unstressed syllables.

right-most foot boundary (e.g. | *paw of the*|; SWW) in an Abercrombian foot, comprising a prominent syllable and multiple following unstressed syllables (Abercrombie 1967).

Glottalisation therefore appears to be employed as a hiatus resolution strategy that maintains the prominence of the foot boundary in the studies described above. The paradigmatic contrast between glottalisation and glide/r-insertion in various prosodic positions can be understood under a featural enhancement framework (Cho 2016). Glottalisation inserts a low sonority element between the surrounding (sonorous) vowels leading to greater syntagmatic contrast between adjacent elements to create boundary enhancement. In contrast, glides and inserted /ɹ/ have higher sonority than glottalisation and hence provide less syntagmatic contrast with surrounding vowels leading to reduced boundary cues (see also Uffmann 2007). Studies of non-hiatus contexts show that glottalisation is often used to mark prominence in vowel onset words in initial positions of prosodic phrases (Blevins 2008; Dilley et al. 1996, Garellek 2014; Pierrehumbert 1995; Redi and Shattuck-Hufnagel 2001) and is considered to be a strengthening strategy at the right edge of a prosodic boundary (Keating 2006) and/or a contrast enhancement strategy (Cho 2005; 2016) to provide syntagmatic separation from the previous syllable as described above.

Glottalisation to resolve hiatus seems to be a recent change in varieties of English, and its use may be increasing (Allerton 2000; Cox et al. 2014; Foulkes 1997). Cox et al. (2014) found that younger AusE speakers used glottalisation more than older AusE speakers to resolve hiatus in WS linking-r contexts. More recently, Cox et al. (2023) conducted a diachronic analysis of a V#V juncture that included the prevocalic determiner *the* (e.g. *the aeroplane*) in a scripted sentence recorded in two cohorts of AusE speakers at either end of a 50-year timespan. They found little glottalisation in speakers from the 1960s, but substantial glottalisation in speakers from the 2010s, suggesting that the use of glottalisation to resolve hiatus is a relatively recent phenomenon in this variety.[4]

Blevins (2008), working in the Evolutionary Phonology framework, which prioritises explanations for phonological patterns based on historical phonetically motivated processes across languages, describes epenthetic segmental glides [j] and [w] as typically originating in intervocalic contexts, whereas sound change involving epenthetic laryngeals originates at prosodic boundaries. Blevins (2008) speculates that the use of subphonemic [ʔ] to mark prosodic boundaries could be associated with boundary-related pitch contours. She describes laryngeal epenthesis (e.g. insertion of glottal stops) as a sound change that begins variably at

**4** The increase in use of glottalisation in hiatus contexts with the prevocalic definite article appears to be linked to a change in the quality of the vowel in the determiner, a change that is seen in multiple varieties of English, but this will not be explored in this paper. See Cox et al. 2023 for more details.

phrase boundaries, progresses to regularisation in that context, then to increasingly lower-level prosodic boundaries, only later becoming common at foot or syllable boundaries. Her observations, from a wide range of languages, lead us to suggest that English is quite advanced with respect to this process. It has also been shown that increasing syntagmatic contrast at prosodic junctures facilitates lexical segmentation by supporting successful parsing of continuous speech (Fougeron and Keating (1997). Cho et al. (2007) found that domain initial strengthening cues lexical segmentation of two-word phrases. Such strategies may be beneficial in contexts where extensive variability of input language may challenge speech processing such as in communities with high levels of linguistic diversity.

Increases in the use of glottalisation to resolve hiatus may therefore be related to the increase in ethnolinguistic diversity taking place in English-speaking countries such as Australia, New Zealand, and the United Kingdom. In a synchronic analysis conducted alongside their diachronic analysis, Cox et al. (2023) also found that young adult speakers of non-mainstream AusE, in this case speakers with Lebanese Arabic language backgrounds, were more likely to use glottalisation to resolve hiatus than their mainstream AusE speaking counterparts. Greater use of glottalisation has also been found in prevocalic definite article hiatus contexts in non-Anglo background speakers from ethnolinguistically diverse communities in New Zealand (Meyerhoff et al. 2020) and in the United Kingdom (Britain and Fox 2009; Cheshire et al. 2011; Fox 2015) compared to Anglo-only background speakers. This is consistent with sociolinguistic research from the United Kingdom regarding hiatus contexts more generally. Britain and Fox (2009) found that in the ethnolinguistically diverse East End district of London, speakers with Bangladeshi backgrounds exhibited greater use of glottalisation in linking-r contexts compared to speakers from the same community with Anglo British[5] backgrounds (Britain and Fox 2009; Fox 2015): male speakers with Bangladeshi backgrounds produced linking-r just over half of the time (55 %) with glottalisation used in the remaining cases, whereas both male and female speakers with Anglo British backgrounds used linking-r in the majority of cases (females: 97 %; males: 94 %) and only seldom used glottalisation. In contexts where the $V_1$ was high, that is in contexts in which the emergence of a glide would be expected, glottalisation was used less often to resolve hiatus compared to linking-r contexts by the speakers with Bangladeshi backgrounds, with glides being used in the majority of cases (j-gliding context: 62 %; w-gliding context: 85 %), but

5 The authors refer to the groups as Bangladeshi and White/Anglo British. Included in the White/Anglo British boys group were also two boys with Anglo/Afro-Caribbean backgrounds. As they lived with a White British parent and belonged to Anglo friendship networks, they were included with the Anglo boys. All of their participants were either born in London or settled there by 3 years of age (see Britain and Fox 2009; Fox 2015 for details).

nevertheless glottalisation was used more frequently than by the speakers with Anglo British backgrounds, who used glides almost exclusively (j-gliding context males/females: 100 %; w-gliding context: females: 100 % males: 96 %).

The studies described above suggest not only that glottalisation is becoming an increasingly dominant strategy for hiatus resolution, but also that this change may be led by speakers from multilingual/ethnolinguistically diverse backgrounds. Such speakers may be regularising the otherwise complex system of resolving hiatus in English (see Britain and Fox 2009) by moving towards a single strategy (i.e. glottalisation) to manage hiatus contexts. This would be consistent with Trudgill's (2017) suggestion that in communities with high levels of language contact and second language learning, more complex features of the dominant language may become levelled among learners, and the levelled patterns may then persist in subsequent generations who acquire the language as an L1. There is increasing sociophonetic evidence that certain sound changes diffuse from (multi) ethnolects to mainstream varieties (e.g. Kerswill et al. 2008).

## 2 Research questions and predictions

The background literature above leads to three main questions driven by phonological, prosodic and sociophonetic theory:

**RQ1:** are j-gliding, w-gliding and linking-r different outcomes of a common implementation strategy used to manage hiatus in AusE?

**RQ2:** how do boundaries of varying strength affect the implementation of syntagmatic contrast between adjacent vowels?

**RQ3:** are speakers from diverse communities advanced with respect to the sound change towards glottalisation as the primary hiatus management strategy in all contexts?

To address the first research question, we analyse whether comparable patterns of use across j-gliding, w-gliding and linking-r are found when comparable contexts are elicited. Details of usage patterns may help to answer this question and propel further studies to consider whether these apparent epenthetic consonants can be considered epiphenomenal or phonological. Few studies have attempted to elicit all three linking environments (but see e.g. Britain and Fox 2009) and hence there is limited understanding of how patterns of use vary across contexts.

With regard to the second research question, syntagmatic contrast is expected to be greatest between syllables at foot boundaries (i.e. when $V_2$ is strong: WS, SS), least within the foot (i.e. when $V_2$ is weak: SW), and intermediate between unfooted syllables (when both $V_1$ and $V_2$ are weak: WW). Maximal enhancement of syntagmatic contrast should be implemented through glottalisation, whereas reduced enhancement should condition the emergence of linking consonants. To our knowledge, there have been no controlled phonetic studies comparing hiatus in phrases across four strength conditions (SW, SS, WW, WS). Such controlled contexts can shed more light on the relationship between implementation of hiatus management and lower-level prosodic boundary types such as these.

Regarding the third research question, studies have found that sound change may diffuse through communities through language contact (Labov 2007; Trudgill 2017). Recently, studies of multiethnolects show diffusion to mainstream varieties (Kerswill et al. 2008). In the case of hiatus management, the use of glottalisation is increasing in several varieties of English and this change appears to be led by speakers from diverse multilingual backgrounds (Britain and Fox 2009; Cox et al. 2023; Meyerhoff et al. 2020). As described above, Blevins (2008) suggests that, in historical sound change across languages, the progression of laryngeal epenthesis begins at strong prosodic boundaries and moves progressively towards use at weaker boundaries. If speakers from diverse backgrounds are leading change, they may be at the forefront in the use of glottal enhancement across all prosodic contexts from higher to lower in the prosodic hierarchy. Speakers from diverse backgrounds are exposed to considerable variation in the ambient language of their communities. How does such diversity affect the processing of speech? One possibility is that increased communicative success in such diverse communities could be facilitated by the strengthening of prosodic boundaries. As discussed above, increasing syntagmatic contrast at prosodic junctures can facilitate more successful parsing of continuous speech (Cho et al. 2007; Fougeron and Keating 1997). This may be particularly useful in ethnolinguistically diverse communities, where listeners do not necessarily share the same language backgrounds and experiences and thus can less easily draw on top-down processing to parse the spoken language compared to more ethnolinguistically homogeneous communities (Harrington et al. 2018; Trudgill 1995, 2011). Variability in the ambient language exposes speakers to variation that can lead to simplification (Trudgill 2017). In the case of hiatus management, simplification could manifest as greater use of a single strategy (i.e. glottalisation) rather than the complementary paradigmatic relationship described above for glottalisation and linking-r (e.g. Yuen et al. 2018). Comparing the hiatus resolution strategies of speakers from a range of backgrounds will help us better understand whether speakers from diverse backgrounds are indeed at the forefront of change towards glottalisation and whether a process of simplification is a plausible explanation.

In order to address these phonological/prosodic and sociophonetic theoretical issues, we present below two analyses of hiatus management. In the first analysis, presented in Section 4.1, we examine hiatus resolution in contexts that have the potential to condition both linking-r as well as gliding (j-gliding and w-gliding), to analyse the effects of prosodic strength of the word boundary (within the foot – SW, and across a foot boundary – SS) and linguistic diversity on the realisation of hiatus. In the second analysis, presented in Section 4.2, we again examine linguistic diversity but in linking-r contexts only and analyse the effects of prosodic strength of the word boundary taking into account both $V_1$ and $V_2$ in four combinations of prosodic strength (SW, SS, WW, WS).

To examine the idea that speakers from multicultural diverse communities are at the forefront of change with regard to employing glottalisation to manage hiatus, we base our analyses on adolescent AusE speakers from a range of areas in Sydney, Australia, that vary in their levels of cultural and linguistic diversity. Contemporary Australian society is highly multicultural, with more than 50 % of the population being first- or second-generation migrants according to the 2021 Census (Australian Bureau of Statistics 2021). This number is even higher in large cities such as Sydney, where over 60 % of residents have a migration background and 42 % of residents speak a language other than English (LOTE) at home (Australian Bureau of Statistics 2022). The most commonly spoken LOTEs are Mandarin, Arabic, Cantonese, Vietnamese, and Hindi (Australian Bureau of Statistics 2022). This unsurprisingly leads to a high degree of linguistic diversity within the population, and in some cases, high levels of language contact in the community. However, there is great variation in the level of linguistic diversity in different parts of the city. In some areas, such as the Northern Beaches district, the majority of residents have an English language background, whereas in other areas, very few residents have English language backgrounds and the majority have LOTE backgrounds. This situation of variable community linguistic diversity and language contact has led to (multi)ethnolectal, non-mainstream varieties of AusE that may be used to express ethnic, non-mainstream (i.e. non-Anglo-Celtic) identities, and, more generally, is thought to contribute to, and perhaps drive, changes in AusE speech processes (Clothier 2019a; Clyne et al. 2001; Cox et al. 2023; Cox and Palethorpe 2011; Grama et al. 2020; Horvath 1985). The data we report on here were collected as part of a larger research project on Multicultural Australian English (Cox 2018), which examines the role of ethnocultural and linguistic diversity in the speech of AusE speaking young people from different areas of Sydney that differ with regard to both the degree of linguistic diversity and the heritage languages spoken.

Based on previous findings discussed above and the three main theoretical issues that we have highlighted, our broad expectations are addressed below:

1. Glottalisation will be more frequent when V2 is strong than when V2 is weak; liaison (i.e. linking-r or gliding) will be more frequent when V2 is weak and less frequent when V2 is strong.

We predict that glottalisation will be used more frequently when $V_2$ is strong, that is, when the hiatus straddles boundaries that are higher in the prosodic hierarchy, in this case the foot boundary (SS). Glottalisation will be less frequent when $V_2$ is weak, that is, at boundaries at lower levels in the prosodic hierarchy within the foot (SW). The patterns of implementation strategies across gliding/linking-r for these two contexts will allow us to posit whether similar or dissimilar processes are involved in each liaison type in these two prosodic contexts. If gliding and linking-r contexts are managed using the same implementation strategies, we would expect similar patterns of glide/linking-r incidence to appear in all contexts. If, on the other hand, linking-r is the result of segmental insertion (as suggested by Yuen et al. 2018) but gliding the result of phonetic interpolation (as suggested by Davidson and Erker 2014; Blevins 2008), different patterns of use should be found. In this case greater levels of gliding should be found compared to incidence of linking-r as interpolation is a phonetically motivated automatic effect whereas linking-r requires phonological insertion and therefore may be more variable.

2. Glottalisation will be more frequent in WS contexts than in SS contexts, and more frequent in WW contexts than in SW contexts.

The varying strengths of the boundaries across the full set of weak and strong vowel combinations (SW, SS, WW, WS) allow us to predict relative levels of glottalisation. The full set of prosodic combinations is only possible for linking-r contexts as described below in Section 3.3. In cases where the hiatus straddles the foot boundary (i.e. SS, WS), the incidence of glottalisation should remain high to enhance the strength of the boundary. It is possible that the WS context could induce greater levels of glottalisation than the SS context to ensure separation between a lower sonority $V_1$ and a higher sonority $V_2$. This prediction is based on research showing that schwa is subject to greater anticipatory coarticulation across the hiatus from $V_2$ to $V_1$ in the WS context (Cohen Priva and Strand 2023). Glottalisation may help to offset some of the potential reduction in separation that coarticulation could induce. In weak $V_2$ contexts, glottalisation will be used more when $V_1$ is weak (WW) (i.e. when the hiatus occurs before an unfooted syllable) than when $V_1$ is strong (SW) (i.e. when the hiatus occurs within the trochaic foot). This scenario is predicted to occur as elements contained within the foot should be subject to the least syntagmatic contrast and hence greatest use of liaison.

3. Glottalisation will be more frequent among speakers from areas with high levels of linguistic diversity.

If speakers from communities with high levels of linguistic diversity are indeed leading a change towards glottalisation as a hiatus resolution strategy in English we would anticipate that the level of diversity should affect usage patterns gradiently, with speakers from high diversity areas using glottalisation the most and those from lower diversity areas using glottalisation the least. If Blevins (2008) is correct that hiatus-resolving glottalisation as a regular sound change progresses from regularisation at phrase boundaries first, through to smaller phrase or word boundaries, and then to foot and/or syllable boundaries, we would expect speakers at the forefront of this change to be using glottalisation more at lower-level boundaries than the other speakers.

# 3 Materials and methods

## 3.1 Participants

141 adolescents (female: 82; male: 58; other: 1) aged 15–18 years (mean age: 15.8) participated in this study as part of the Multicultural Australian English project (Cox 2018; Gibson et al. 2022). Participants were Australian born, with the exception of three participants who migrated to Australia at a young age (one born in France who migrated at 6 months; one born in the UK who migrated at 4 years; one born in the US who migrated at 5 years). All participants completed both primary and secondary school (up to their current level) in Australia and had lived in their local area for at least the past 10 years.

## 3.2 Categorisation of linguistic diversity

Participants were recruited from high schools in several areas of Sydney, selected to sample varying levels of community language diversity/homogeneity. One of the areas participants were recruited from, the Northern Beaches, has relatively low levels of community language diversity, with the majority of residents in this area having an English language background. For example, 86 % of residents in the Northern Beaches area of Pittwater speak only English at home (hence a LOTE is only spoken at home by 14 % of the area's residents) (Australian Bureau of Statistics 2016a). The other areas participants were recruited from are all located in the inner and outer Western Suburbs and have considerably higher levels of community language diversity, with many residents having LOTE backgrounds. However, substantial variation exists in the extent of linguistic diversity in these areas. For example, 13 % of residents in the suburb of Cabramatta speak only English at home (hence a LOTE is spoken by 87 % of residents), whereas in the suburb of Girraween 40 % of residents speak only English at home (hence 60 % of residents speak a LOTE at home) (Australian Bureau of Statistics 2016b). Accordingly, participants in our study reside in suburbs with varying levels of community language diversity.

In order to account for and analyse this variation in community language diversity, we assigned participants to one of three diversity categories based on the level of linguistic diversity in their suburb of residence: *non-diverse*, *diverse*, and *super-diverse*. The proportion of residents within a postcode who spoke only English at home, as measured in the 2016 census[6] (Australian Bureau of Statistics 2016b), was taken as a proxy for the level of linguistic diversity within that postcode, and the three groups were defined according to observed clusters in the data. Participants in the non-diverse group lived in postcodes in which 84–90 % of residents spoke only English at home; participants in the diverse group lived in postcodes in which 36–72 % of residents spoke only English at home; participants in the super-diverse group lived in postcodes in which 12–32 % of residents spoke only English at home. Table 1 details the number of speakers in each of these groups. We note that there is an unbalanced gender mix in the cohort across the board that also manifests itself in the diverse group. As such, we will not examine the role of gender in this paper, although we acknowledge that gender may play a role in hiatus resolution (e.g. Cox et al. 2023; Hay and Maclagan 2012; Hay and Sudbury 2005).

**Table 1:** Details of participants included in three diversity groups based on linguistic diversity within postcode.

| Diversity group | English only at home | Number of participants (female; male; other) | Participants with LOTE background |
|---|---|---|---|
| Non-diverse | 84–90 % | 39 (19; 19; 1) | 7.7 % |
| Diverse | 36–72 % | 46 (37; 9; 0) | 67.4 % |
| Super-diverse | 12–32 % | 55 (25; 30; 0) | 92.7 |

6 At the time this study was designed, as well as during data collection and our initial analysis, the 2016 census data was the most recent data available. Data from the 2021 census has recently been made available; however, for the sake of consistency, we have chosen to continue with the original 2016 values used to specify diversity groups in this analysis. We note that changes to the proportions are minimal and do not affect our interpretations.

As shown in Table 1, most of the participants in the non-diverse group had English-speaking backgrounds. In both the diverse and super-diverse groups the majority of participants had non-English speaking backgrounds, with almost all participants in the super-diverse group having a LOTE background. This demonstrates that the census-based diversity categories reflect the linguistic diversity of the participants well. The participants with LOTE backgrounds came from a wide variety of language backgrounds, with many languages only represented by one or two participants. This therefore precludes an analysis based on participants' specific language backgrounds. The most frequent language backgrounds in our sample were Vietnamese, Khmer, Cantonese, Mandarin and Arabic, which corresponds with the most common non-English languages spoken in the community (Australian Bureau of Statistics 2022).[7]

## 3.3 Procedure

All participants took part in a recording session facilitated by a research assistant recruited from the local area. 84 of the speakers were recorded in a face-to-face setting in a quiet room of their school; six participants were recorded in a room at a local library; three participants were recorded in their (or their friend's) home. In addition, 48 speakers were remotely recorded while at school during periods in the COVID-19 pandemic in which visitors were not permitted to attend NSW schools due to restrictions on face-to-face contact. In the remote recordings, an RA facilitated the session via a Zoom video call, but the recording was captured locally on a laptop in a quiet location at the child's school. Face-to-face participants were recorded through a RODE HS2 headset microphone to a Zoom H6 recorder. Recordings were made with a sample rate of 44.1 kHz and 16 bit resolution. Remote participants were recorded through an online digital recorder (https://mmig.github.io/speech-to-flac/) with a sample rate of either 44.1 kHz or 48 kHz (depending on the device specifications) and 16 bit resolution. Face masks were not worn by participants while taking part in the recording sessions. Although the recordings captured remotely do not have the same level of quality as the recordings captured face-to-face, they were nevertheless suitable for analysis, and each item was checked for excessive background noise or any other anomalies during processing and annotation.

Prior to the recording session, participants' parents provided informed consent and completed a demographic background questionnaire. At the recording session,

7 As mentioned above, Hindi is the fifth most common LOTE spoken in Australia. Our data set contains only three participants with Hindi background. It also contains three participants each with Tamil, Gujarati, and Punjabi backgrounds, and one with Telegu background.

the participants also provided their informed consent, and completed an ethnic orientation survey modelled on Hoffman and Walker (2010) and Clothier (2019b). Participants' speech was audio recorded while they engaged in a picture naming task whereby 224 single words and short phrases were elicited through the presentation of images on a computer screen. Participants were also recorded in a spontaneous conversation task with a peer and a research assistant. Only data from the short phrases are analysed in this paper. Data for one participant's picture naming task were lost; therefore, the current analysis is restricted to data from 140 participants (female: 81; male: 58; other: 1).

A short phrase task eliciting $V_1\#V_2$ hiatus contexts was embedded within the picture naming task, in which participants produced 38 two-word phrases designed to sample a range of potential hiatus contexts upon presentation of images. A subset of 30 items were elicited through a counting protocol, and included the numbers *two*, *three*, or *four* as the left-edge word, allowing us to compare three different hiatus contexts determined by the prosodically strong vowel (/ʉː/, /iː/, /oː/) in $V_1$ position. These three hiatus contexts with strong $V_1$ elicited potential w-gliding, j-gliding and linking-r respectively. Ten nouns were selected as the right-edge word in order to vary the prosodic strength of $V_2$. The nouns selected to elicit strong $V_2$ were *eagles, ears, eyes, ubers, oars, arms*, sampling high front (/iː/ in *eagles*, /ɪə/ in *ears*), central (/ʉː/ in *ubers*), back (/oː/ in *oars*), and low (/ɑe/ in eyes, /ɐː/ in arms) vowels, and those selected to elicit weak $V_2$ (/ə/) were *alarms, awards, exams, o'clock*. The remaining phrases were constructed with the possessive determiner *her* as the left-edge word to elicit a prosodically weak /ə/ vowel in the $V_1$ position paired with eight of the same nouns as the right-edge word to capture both strong and weak $V_2$. This hiatus context with weak $V_1$ elicited potential linking-r contexts only, as the weak vowel schwa does not satisfy the height requirement of the gliding liaison contexts.[8] Items with a number in the left-edge position were elicited through the counting task described above in which participants were shown the relevant number of images of the respective noun on the screen (e.g. *four eagles*); items with the possessive determiner in the left-hand position were elicited through a task allocating possession of the respective nouns (e.g. *(these are … ) her eyes*). In all cases the nouns in right-edge position had previously been elicited in the picture naming task, hence participants were familiar with them. Table 2 provides an overview of the 38 elicited phrases and their prosodic environments.

8 We note that the inclusion of items ending in other unstressed vowels such as happY and GOAT in addition to the schwa as captured would enable comparison of weak $V_1$ in gliding and linking-r contexts, although we leave this to future research to explore.

**Table 2:** Summary of elicited phrases and prosodic strength of left-edge and right-edge vowels.

| Left-edge word | $V_1$ strength | Right-edge word | $V_2$ strength | Prosodic environment |
|---|---|---|---|---|
| two/three/four | Strong | arms/eagles/ears/eyes/oars/ubers | Strong | SS |
| two/three/four | Strong | alarms/awards/exams/o'clock | Weak | SW |
| her | Weak | arms/eagle/ears/eyes/ubers | Strong | WS |
| her | Weak | alarm/award/exam | Weak | WW |

## 3.4 Data processing and analysis

Audio files were orthographically transcribed, then segmented into phonemes and force aligned through WebMAUS (Kisler et al. 2017) using an AusE model. Segment boundaries were hand corrected in Praat (Boersma and Weenik 2022) by two phonetically trained annotators and each item was labelled according to the strategy employed to resolve the hiatus through a combination of auditory analysis and visual inspection of the waveform and spectrogram. Each item was labelled as an example of one of the following four categories:

– rhotic/glide (depending on whether it occurred in a linking-r or gliding context, with either [j] or [w] possible in gliding contexts), evident in a lowered F3 and perceived rhoticity in the case of a rhotic, and a continuation of clear formant structure and the percept of a glide in the case of [j, w];
– glottalisation: including both full glottal stops and (incomplete) glottal constriction resulting in laryngealised phonation at the hiatus juncture, evident as a period of full glottal stop closure and/or irregular glottal pulses in the waveform and spectrogram, and/or the auditory percept of a glottal stop or glottalisation;
– true hiatus: in which there was neither evidence of glottalisation nor evidence/impression of an intervening rhotic/glide;
– elision: this was observed in a small number of items in which a weak $V_2$ was elided, most commonly with the right-edge word *o'clock* (e.g. *four clock* rather than *four o'clock*).

Additionally, a number of items ($n$ = 93) in the linking-r context were labelled as producing the percept of rhoticity in addition to the hiatus being resolved by glottalisation. These occurred in the linking-r context with both prosodically weak

($n$ = 50) and prosodically strong ($n$ = 43) left-edge vowels. Some previous studies (Cox et al. 2014; Mompean 2022) have also reported the co-occurrence of glottalisation with linking-r, but only in a small number of items. For the purposes of the statistical analysis, these items were included in the glottalised category, although we include these as a separate category in visualisations of the raw data in Section 4.[9] We also discuss assessing rhoticity in our participants in Section 3.5.

130 items were excluded from analysis; these were primarily due to the inclusion of a pause at the hiatus juncture ($n$ = 118). The majority of the pauses were quite long (mean = 405 ms); however, there were a small number that were short (~50 ms) but nevertheless created the percept of a pause due to the presence of a pitch reset. Other items were excluded due to errors/disfluencies in production ($n$ = 8) or a glide being produced in a linking-r context (e.g. f[oːj]ubers; f[oːw]eagles) ($n$ = 5). We note that gliding in a linking-r context may potentially be an alternative strategy to resolve hiatus for some speakers; however, due to the low occurrence of this in the data, this will not be explored here.

Both of the annotators relabelled 10 % per cent of their annotated data to assess intra-annotator reliability. In addition, the first author relabelled 10 % of the annotated data to assess inter-annotator reliability. Reliability was tested with the irr package (Gamer et al. 2019). In all cases there was strong agreement among the annotators (McHugh 2012) (intra-annotator: $k$ = 0.95; $z$ = 19.7; $p$ < 0.0001 & $k$ = 0.86; $z$ = 8.06; $p$ < 0.0001; inter-annotator: $k$ = 0.93; $z$ = 30; $p$ < 0.0001). Moreover, all items that were labelled as cases of elision or true hiatus were double checked by the first and second authors.

The data were then imported into a database using emuR (Winkelmann et al. 2017) for further analysis in R (R Core Team 2023).

## 3.5 Rhoticity score

Despite AusE being regarded as a non-rhotic variety of English (Cox and Palethorpe 2007), in a preliminary analysis we identified variable non-prevocalic rhoticity in some AusE speakers from ethnolinguistically diverse areas of Sydney (Gibson et al. 2022). Theoretically, if a speaker produces non-prevocalic rhoticity, they may be expected to show rhoticity in what would otherwise be a linking-r context (e.g. *four oars*). That is, for these speakers such contexts may not be hiatus contexts at all, and, therefore, we might expect them not to use glottalisation (or any other hiatus resolution strategy). By the same logic, this might also be the case for speakers with variable rhoticity, though this could be modulated by their level of rhoticity.

9 We also analysed the data with these items excluded, and the results were essentially the same.

Therefore, in order to account for this possibility in our modelling, we assigned each participant a rhoticity score. This was based on how frequently they produced rhoticity in a set of 35 words from the picture naming task that have orthographic <*r*> in a non-prevocalic position (e.g. *dirt, chair, girl, star*). This was auditorily assessed by the first and second authors, and 10 % of the items were assessed by both authors, with very high agreement ($k = 0.89$; $z = 16.7$; $p < 0.0001$). The number of items per speaker produced with rhoticity was divided by the overall number of items with orthographic <*r*> and multiplied by 100 to provide the rhoticity score as percentage. 66 % (92/140) of the participants displayed no evidence of non-prevocalic rhoticity. The remaining 34 % of participants (48/140) produced at least one item with rhoticity: 11 % (16/140) produced less than 10 % of items with rhoticity; 19 % of participants (27/140) produced rhoticity in over 10 % of items; 4 % of participants (5/140) produced rhoticity in over three quarters of the items.

## 3.6 Statistical analysis

Modelling was conducted by generalised linear mixed effects regression using the lme4 (Bates et al. 2015) and afex packages (Singmann et al. 2021). Two analyses were conducted. First, we analysed the items with a strong $V_1$ (i.e. those with *two, three, four* as the left-edge words). This allowed us to examine whether hiatus resolution strategies differed according to hiatus context, prosodic strength of $V_2$, and across diversity groups. The dependent variable was whether hiatus resolution was resolved through glottalisation or another strategy (combining the linking-r/gliding, true hiatus and elision). Fixed factors were hiatus context (linking-r, j-gliding, w-gliding), $V_2$ strength (strong/weak) and diversity group (non-diverse, diverse, super-diverse), and the rhoticity score per participant (centred and scaled) was included as a control factor. All two- and three-way interactions between hiatus context, $V_2$ strength, and diversity group were modelled. Random intercepts were included for participant and for $V_2$ vowel quality.

The second analysis included all of the items with a linking-r hiatus context only (i.e. those with *four* and *her* as the left-edge words). As these items included both strong and weak vowels in $V_1$, this enabled an examination of the prosodic strength of the boundary according to both $V_1$ and $V_2$, and linguistic diversity. As in the first analysis, the dependent variable was whether hiatus was resolved through glottalisation or another strategy (in this case combining linking-r, true hiatus and elision). Fixed factors were $V_2$ strength (strong/weak) and diversity group (non-diverse, diverse, super-diverse) as in the first analysis, as well as $V_1$ strength (strong/weak). Here we also included the rhoticity score per participant (centred and scaled) as a control factor. We modelled all two- and three-way interactions between $V_2$ strength, diversity group, and $V_1$ strength. Random intercepts were included for participant. Additional elements incorporated into the random effects structure resulted in warnings of a singular fit, so these were excluded in the final model.

For each analysis, we report overall results for the model term as calculated by the afex package (Singmann et al. 2021) based on Type III likelihood ratio tests. Model summaries of the generalised mixed effects regressions models are provided in Tables 6 and 7 in the Appendix. Pairwise comparisons (with Tukey HSD corrections where necessary) were conducted on significant interaction terms utilising the emmeans package (Lenth 2020).

# 4 Results

## 4.1 Analysis of hiatus contexts (linking-r and gliding)

The analysis of the various hiatus contexts (linking-r and gliding) included 4,105 items, all produced with a prosodically strong vowel in the left-edge word (*two, three, four*). This analysis did not include the 1,085 items produced with a prosodically weak vowel in the left edge word (*her*). Overall, in 62 % of items (2,555/4,105) hiatus was resolved through glottalisation (including 43 items with evidence of rhoticity and glottalisation), compared to 35 % (1,444/4,105) with a rhotic or glide (depending on the particular hiatus context). Additionally, in 1.5 % of items (64/4,105) we observed true vowel hiatus, and in 1 % of items (42/4,105) $V_2$ was elided (all were weak vowels in the right-edge word *o'clock*).

The results of the generalised mixed effects logistic regression model are shown in Table 3.

**Table 3:** Summary of type III likelihood ratio tests on generalised linear mixed effects regression model analysing hiatus resolution across hiatus contexts (linking-r and gliding).

| | *df* | $\chi^2$ | *p* | |
|---|---|---|---|---|
| Rhoticity score | 1 | 2.82 | 0.093 | |
| $V_2$ strength | 1 | 16.2 | <0.001 | *** |
| Diversity group | 2 | 15.71 | <0.001 | *** |
| Hiatus context | 2 | 150.61 | <0.001 | *** |
| $V_2$ strength: diversity group | 2 | 7.99 | 0.018 | * |
| $V_2$ strength: hiatus context | 2 | 13.03 | 0.001 | ** |
| Diversity group: hiatus context | 4 | 7.24 | 0.124 | |
| $V_2$ strength: diversity group: hiatus context | 4 | 2.98 | 0.561 | |

Asterisks represent significant effects: * = < 0.05; ** = < 0.01; *** = < 0.001.

There was a significant interaction between $V_2$ strength and hiatus context. In all three hiatus contexts glottalisation was used more when $V_2$ was strong, as expected. There was also more glottalisation in the linking-r context than in the other two hiatus contexts, regardless of $V_2$ strength. This is particularly the case when $V_2$ is strong, where glottalisation is almost categorical in the linking-r context, but lower in the w-gliding context, and lower again in the j-gliding context. Post-hoc analysis showed that glottalisation is significantly more likely in the linking-r context than the other two contexts when $V_2$ is strong (SS) (both $p < 0.0001$), and also in the w-gliding context compared to the j-gliding context ($p = 0.0004$). In cases in which $V_2$ is weak (SW), there was substantially more linking-r/gliding and less glottalisation. Nonetheless, glottalisation was significantly more likely in the linking-r context than in the other two contexts (both $p < 0.0001$). The difference between the j- and w-gliding contexts was not significant when $V_2$ was weak. These effects can be seen in Figure 1, which illustrates the raw proportions of each hiatus resolution strategy according to $V_2$ strength and the different hiatus contexts. Note that items in which both rhoticity and glottalisation occur are shown as a separate category here, although they were categorised as glottalised in the statistical analysis. Figure 1 also shows that, despite being relatively infrequent overall, elision and true vowel hiatus occurred primarily in the linking-r context (elision: $n = 37$; true vowel hiatus: $n = 61$), with few items in the j-gliding (elision: $n = 4$; true vowel hiatus: $n = 2$) and w-gliding contexts (elision: $n = 1$; true vowel hiatus: $n = 1$).

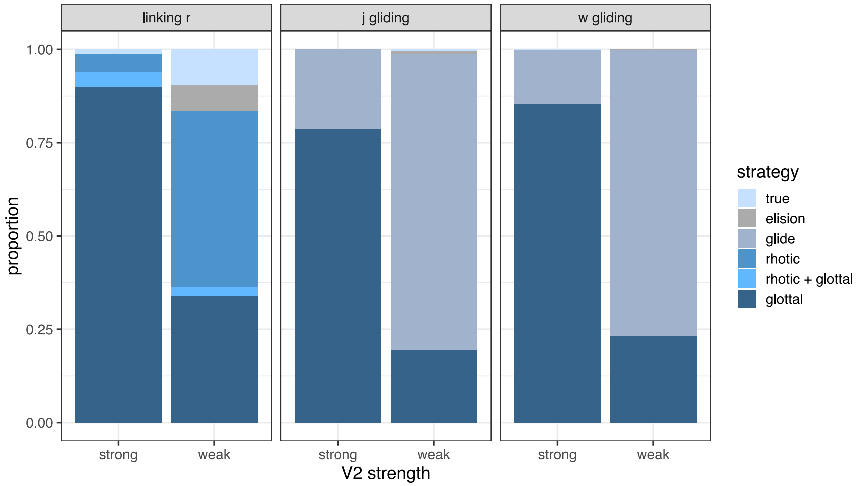


**Figure 1:** Proportions of hiatus resolution strategies according to $V_2$ strength and hiatus context.

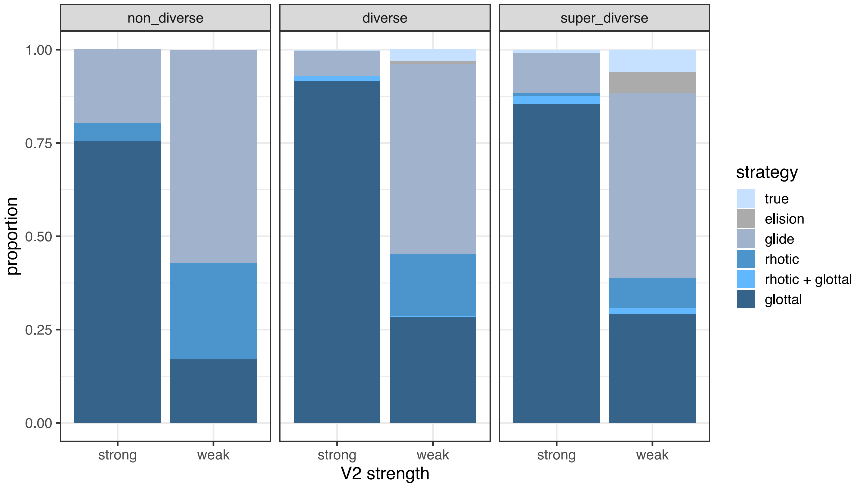


**Figure 2:** Proportions of hiatus resolution strategies according to $V_2$ strength and diversity group (including both linking-r and gliding contexts).

We also found a significant interaction between $V_2$ strength and diversity group. As discussed above, glottalisation was used most frequently to resolve hiatus when $V_2$ was strong, and this tendency was visible in all of the groups. Nevertheless, the non-diverse group was less likely to resolve hiatus with glottalisation than either of the other two groups in both $V_2$ strength conditions. This can be seen in Figure 2, which illustrates the raw proportions of each hiatus resolution strategy according to $V_2$ strength and diversity group, with results pooled across the linking-r and gliding environments. When $V_2$ was strong the non-diverse group resolved hiatus with glottalisation in 76 % of items compared to 93 % in the diverse and 88 % in the super-diverse groups. Post-hoc analysis showed that the difference between the non-diverse group and the diverse group was significant ($p$ = 0.0001), and the difference between the non-diverse group and super-diverse group approached significance ($p$ = 0.0557). The difference between the diverse and superdiverse groups did not reach significance.

When $V_2$ was weak, the non-diverse group were significantly less likely to utilise glottalisation than both the diverse ($p$ = 0.0127) and the super-diverse ($p$ = 0.0115) groups, whereas the difference between the diverse and super-diverse groups was not significant. The non-diverse group resolved hiatus with glottalisation in 17 % of items when $V_2$ was weak, compared to 29 % in the diverse and 31 % in the super-diverse groups.

Figure 2 shows that in addition to increased glottalisation, there are a number of other differences in the hiatus resolution strategies used by the diverse and super-diverse groups compared to the non-diverse group, particularly when $V_2$ is weak: both groups use less gliding (non-diverse: 57 %; diverse: 51 %; super-diverse: 49 %) and, more prominently, less linking-r (marked as *rhotic* in the figure) (non-diverse: 26 %; diverse: 17 %; super-diverse: 8 %). Moreover, both of these groups use elision and true vowel hiatus in hiatus contexts, which, with the exception of a single case of elision, is not observed in the non-diverse group. This is particularly the case for the super-diverse group, who produce each of these strategies in 6 % of items with a weak $V_2$.

## 4.2 Analysis of linking-r contexts only

The analysis of linking-r contexts included 2,449 items. In this set, items were produced with either a prosodically strong (*four*) or weak (*her*) $V_1$, in addition to varying in terms of whether $V_2$ was strong or weak. Thus, 1,364 of the items in this analysis were also included in the analysis above (from the phrases containing *four*), supplemented with an additional 1,085 items containing *her* as the left-edge word. Hiatus was resolved by glottalisation in 74 % of all items (1,715/2,449) (including 93 items with evidence of both rhoticity and glottalisation), compared to 21 % (512/2,449) that included a linking-r. As in the previous analysis, we also observed items with true vowel hiatus (3 %; 81/2,449) and elision (2 %; 48/2,449).

The model results are shown in Table 4. There was a significant three-way interaction between $V_2$ strength, diversity group, and $V_1$ strength. Figure 3 illustrates this effect. The proportion of items produced with glottalisation in each prosodic

**Table 4:** Summary of type III likelihood ratio tests on generalised linear mixed effects regression model analysing hiatus resolution in linking-r contexts.

| | *df* | $\chi^2$ | *p* | |
|---|---|---|---|---|
| Rhoticity score | 1 | 0.76 | 0.384 | |
| $V_2$ strength | 1 | 1,007.34 | <0.001 | *** |
| Diversity group | 2 | 16.81 | <0.001 | *** |
| $V_1$ strength | 1 | 4.27 | 0.039 | * |
| $V_2$ strength: diversity group | 2 | 1.56 | 0.459 | |
| $V_2$ strength: $V_1$ strength | 1 | 2.58 | 0.108 | |
| Diversity group: $V_1$ strength | 2 | 11.9 | 0.003 | ** |
| $V_2$ strength: diversity group: $V_1$ strength | 2 | 10.32 | 0.006 | ** |

Asterisks represent significant effects: * = < 0.05; ** = < 0.01; *** = < 0.001.

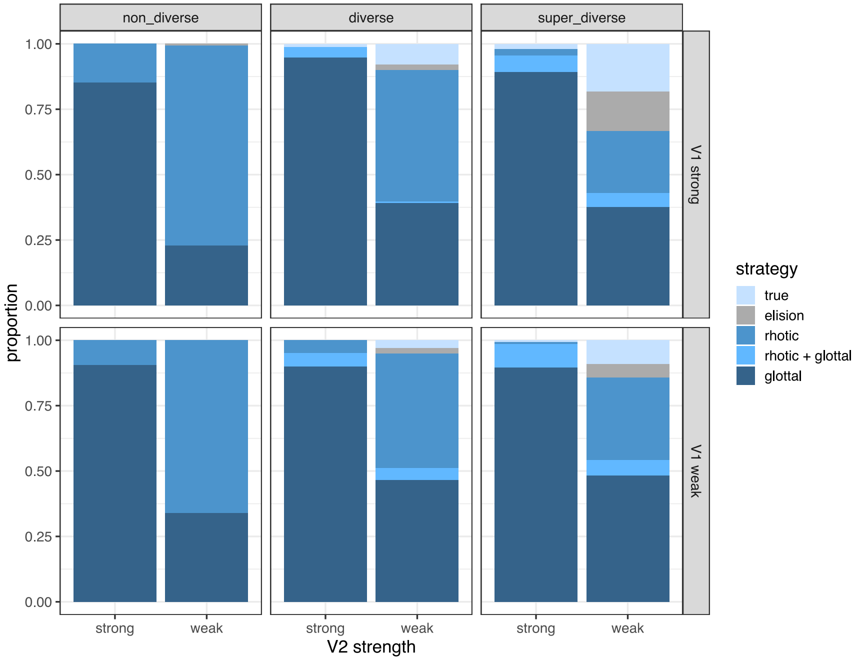


**Figure 3:** Proportions of hiatus resolution strategies according to $V_2$ strength, diversity group, and $V_1$ strength in linking-r contexts.

environment according to diversity group is also shown in Table 5. As in the previous analysis, glottalisation was more frequently used to resolve hiatus when $V_2$ was strong; this was the case for all diversity groups and in both $V_1$ strength conditions (i.e. more glottalisation in SS vs. SW, and in WS vs. WW in all groups: all $p < 0.0001$). However, there were differences between the groups, with the non-diverse group using less glottalisation than the other two. Post hoc analysis shows that the difference between the non-diverse group and the super-diverse group was significant when $V_1$ was strong (SS) ($p = 0.0360$) and when $V_1$ was weak (WS) ($p = 0.0290$). The

**Table 5:** Proportion of items produced with glottalisation according to prosodic environment and diversity group in linking-r context.

| Diversity group | SS | WS | SW | WW |
|---|---|---|---|---|
| Non-diverse | 0.85 | 0.91 | 0.23 | 0.34 |
| Diverse | 0.99 | 0.95 | 0.40 | 0.51 |
| Super-diverse | 0.96 | 0.99 | 0.43 | 0.54 |

difference between the non-diverse group and the diverse group was also significant in the strong $V_1$ condition (SS) ($p$ = 0.0003) with the diverse group producing more glottalisation than the non-diverse group, but not in the weak $V_1$ condition (WS). We found no significant differences between the diverse and super-diverse group in either $V_1$ condition when $V_2$ was strong (WS, SS). Post hoc analysis also shows that within the groups the difference between SS and WS was significant for both the diverse ($p$ = 0.0173) and super-diverse ($p$ = 0.0410) groups, whereas the non-diverse group showed a trend ($p$ = 0.0576).

When $V_2$ was weak, all of the diversity groups produced less glottalisation and increased use of linking-r (marked as *rhotic* in the figure) compared to when $V_2$ was strong, although this effect was strongest in the non-diverse group. All of the diversity groups also produced more glottalisation when $V_1$ was weak (WW) than when it was strong (SW) ($p$ = 0.02 or lower). The difference between the non-diverse group and the super-diverse group was significant in both $V_1$ conditions (strong, SW: $p$ = 0.0061; weak, WW: $p$ = 0.0333). The difference between the non-diverse group and the diverse group was also significant when $V_1$ was strong (SW) ($p$ = 0.0175), but not when $V_1$ was weak (WW). No significant differences were found between the diverse and super-diverse groups in either $V_1$ condition when $V_2$ was weak (SW, WW).

# 5 Discussion

Our first prediction for this study was that we would observe more frequent use of glottalisation to resolve hiatus when $V_2$ was strong than when $V_2$ was weak, and, correspondingly, less liaison (i.e. linking-r or gliding) when $V_2$ was strong, and more liaison when $V_2$ was weak. Across both analyses, this was indeed shown to be the case: overall, in the analysis of hiatus contexts (linking-r and gliding, Section 4.1), 86 % of items were glottalised when $V_2$ was strong, compared to 26 % when $V_2$ was weak. In the analysis of linking-r contexts (Section 4.2), 94 % of items were glottalised overall when $V_2$ was strong, compared to 41 % when $V_2$ was weak. Glottalisation thus appears to be the preferred strategy for resolving hiatus when the vowel on the right-edge of the hiatus context is strong (i.e. at the foot boundary); linking-r and gliding are primarily restricted to hiatus contexts with a weak $V_2$. This is in line with previous studies (Broadbent 1991; Cox et al. 2014; Davidson and Erker 2014; Foulkes 1997; Mompean 2022; Mompeán and Gómez 2011; Uffmann 2007; Yuen et al. 2018) and supports the idea of a conditioned complementary distribution based on the prosodic strength of the right-edge vowel. As discussed above, glottalisation in this prosodic position produces a drop in sonority between adjacent vowels, which would contribute to maintaining syntagmatic contrast supporting the prominence of the word/foot boundary. This is consistent with its implementation as a marker of prominence more generally (Dilley et al. 1996, Garellek 2014; Pierrehumbert 1995; Redi and Shattuck-Hufnagel 2001; Uffmann 2007).

With regard to our first research question, we also investigated whether similarities or differences would be found in the use of glottalisation in the various hiatus contexts if the same implementation strategies were used in linking-r and gliding. Overall, more glottalisation was found in the linking-r context than in the two gliding contexts (linking-r: 71 %; j-gliding: 55 %; w-gliding: 61 %). This effect holds both when $V_2$ is strong – with glottalisation near categorical in the linking-r context (94 %), but somewhat less frequent in the gliding contexts (j-gliding: 79 %; w-gliding: 85 %) – and when $V_2$ is weak (linking-r: 36 %; j-gliding: 19 %; w-gliding: 23 %). Although slightly more glottalisation was observed in the w-gliding compared to the j-gliding context (and this difference was significant when $V_2$ was strong), in both prosodic environments the gliding contexts appear to pattern together, and both display substantially less glottalisation than the linking-r context. Seen from another angle, in the linking-r context only 5 % of items were realised with r-sandhi when $V_2$ was strong, compared to 21 % with a glide in the j-gliding context and 14.5 % in the w-gliding context. When $V_2$ was weak, just under half of the linking-r context items were realised with r-sandhi (47 %), compared to 79 % and 77 % of items in the j-gliding and w-gliding contexts respectively. This may suggest that different processes are at work in the realisation of the various hiatus contexts. Davidson and Erker (2014) suggest that in American English glides in hiatus contexts are epiphenomenal and surface due to transitional phonetic processes (Heselwood 2006): when the right-edge vowel is strong, the prosodic boundary is marked by glottalisation; otherwise, the percept of a glide emerges through the vowel to vowel transition (Blevins 2008). This is essentially compatible with our results (although we find approximately 20 % of items with a strong $V_2$ are nevertheless not marked by glottalisation). In the linking-r context, however, only approximately half of the items with a weak $V_2$ are realised with linking-r, which is not consistent with an epiphenomenal transition. Taken together with the finding of Yuen et al. (2018) that there is evidence of articulatory planning for linking-r, it appears to be the case that linking-r in AusE is inserted rather than epiphenomenal. Linking glides on the other hand show different patterns of incidence that may be more reflective of a transitional effect. Future studies are needed to examine the production and perception of epenthetic compared to lexical consonants, and also to examine lexical compared to hiatus-resolving (and potentially epiphenomenal) glides.

Our second prediction was that glottalisation would be more frequent when $V_1$ was weak than when $V_1$ was strong. In the analysis of linking-r contexts, we also examined whether the strength of the left-edge vowel ($V_1$) had an effect on the strategies speakers use to manage hiatus. In line with our second prediction, and consistent with Cox et al. (2014), we found that when $V_2$ is weak, glottalisation is more likely with a weak $V_1$ (WW) than with a strong $V_1$ (SW). That is, when there are two adjacent weak vowels (in unfooted syllables e.g. *her alarm*), glottalisation is more likely than when there is a single weak vowel following a strong vowel within the same foot (e.g. *four alarms*). We suggest that this effect may be associated with the close connection required for elements within the foot which would be subject to the least syntagmatic contrast. This difference between WW and SW was found in all of the diversity groups. We predicted that for WS and SS contexts, high levels of glottalisation would occur to enhance the strength of the foot boundary. We proposed that WS context could induce more glottalisation than the SS context to ensure the low sonority, coarticulation-susceptible schwa $V_1$ would be separated from the higher sonority $V_2$. While we found some differences between the WS (e.g. *her arms*) and SS (e.g. *four arms*) prosodic environments, these were relatively small and high rates of glottalisation (above 90 %) were observed in all cases, apart from in the SS context in the case of the non-diverse group, where slightly less frequent glottalisation was observed (85 %) (see Table 5 for details). While this result may perhaps hint at a tendency for less use of glottalisation as a hiatus resolution strategy in this particular prosodic environment, we suggest that it is rather a reflection of the overall lower use of glottalisation in this group of speakers (see discussion of linguistic diversity below). It appears that the strength of the left-edge vowel matters little if the right-edge vowel is strong; in both cases (WS and SS) glottalisation use is high. But if the right-edge vowel is weak (SW, WW), there is an effect of left-edge vowel strength. Thus, the likelihood of glottalisation as a hiatus breaker according to prosodic environment (particularly in linking-r contexts) can be expressed as: SS ≈ WS > WW > SW.

Our final prediction relates to the sociophonetic question of whether speakers from parts of Sydney with high levels of ethnolinguistic diversity would be leading a change towards more frequent use of glottalisation as a hiatus resolution strategy than speakers from lower diversity areas, and whether this effect should be gradient across diversity levels. In our first analysis incorporating both gliding and linking-r contexts, speakers from the non-diverse group resolved hiatus with glottalisation less frequently than the other two groups: in 52 % of items in the full analysis of hiatus contexts compared to 67 % in the diverse group and 65 % in the super-diverse group. In the linking-r analysis, the non-diverse group glottalised in 64 % of items compared to 77 % in the diverse group and 78 % in the superdiverse group. As was shown above, the non-diverse group produced less glottalisation both when $V_2$ was strong and when it was weak in both analyses. However, the contrast between the diversity groups was stronger when the right-edge vowel was weak. The non-diverse group exhibited greater evidence of complementary distribution between glottalisation and liaison according to $V_2$ strength: glottalisation in strong $V_2$ contexts and liaison in weak $V_2$ contexts. The diverse groups, on the other hand, used more glottalisation in both $V_2$ contexts. When the right-edge vowel was strong, glottalisation was the dominant strategy for speakers in all diversity groups, with near categorical use. Interestingly, the diverse and super-diverse groups appeared to pattern together, and away from the non-diverse group, in their use of glottalisation. Indeed, we identified no significant differences between these two groups in either analysis.[10] This suggests that the progression of glottalisation as a hiatus resolution strategy (across all prosodic contexts) as an ongoing change in AusE is being led by speakers in ethnolinguistically diverse communities, but that the degree of linguistic diversity within the diverse communities does not appear to be driving this effect.

In their analysis of hiatus resolution in prevocalic definite article contexts (e.g. *the aeroplane*), Cox et al. (2023) also found speakers from non-mainstream AusE backgrounds (specifically those with Lebanese backgrounds) appeared to be at the forefront of the change, and similar results have been found in ethnolinguistically diverse communities for other varieties of English (Britain and Fox 2009; Fox 2015; Meyerhoff et al. 2020). Cox et al. (2023) speculated as to whether the increased use of glottalisation in their speakers may have been influenced by their Arabic language heritage, the phonology of which requires glottal stops before otherwise onsetless syllables. While we cannot rule out that transfer effects may play a role for some speakers of some non-English language backgrounds – which would contribute to the 'feature pool' of available options within the community (Cheshire et al. 2011) – this alone would not explain the increased use of glottalisation as a hiatus breaker in speakers from a broad range of language backgrounds as are represented in our study. Rather, we suggest that the increased use of glottalisation in ethnolinguistically diverse communities may be driven by regularisation of the complex English hiatus resolution system, as may be expected in communities with high levels of language contact (Britain and Fox 2009; Cox et al. 2023; Trudgill 2010; Trudgill 2017). It should, however, be pointed out that this apparent regularisation of hiatus resolution is not restricted to the speakers from ethnolinguistically diverse areas; the non-diverse group also showed higher rates of glottalisation as a hiatus breaker than have been reported in previous studies of comparable contexts in AusE. For example, Cox et al. (2014) found hiatus to be resolved by glottalisation in just over half of all items in WS

**10** We did, however, observe a trend towards more frequent glottalisation in the diverse group when $V_2$ was stressed (and when $V_1$ was also strong in the linking-r analysis), where all groups used high levels of glottalisation, but the diverse group slightly higher. This may also be linked to the use of more alternative hiatus strategies in the super-diverse group, which we discuss below.

linking-r contexts, in 14 % of items in SW contexts and in 22 % of items in WW contexts in their analysis of data recorded in the early-mid 1990s. Our non-diverse group produced glottalisation in 91 %, 23 %, and 34 % of items in these respective contexts. This shows that while the pattern of which prosodic contexts glottalisation is used most remains consistent (and this is also consistent in all three of our diversity groups), the frequency with which this occurs appears to have increased substantially over time, as would be expected for a change in progress. This observation of increased use of glottalisation as a change in progress is also consistent with previous findings for hiatus resolution with the prevocalic definite article (Cox et al. 2023). Therefore, one may assume that the change towards regularisation in AusE hiatus contexts, with glottalisation as the dominant resolution strategy, will continue to progress in the prosodic environments with weak right-edge vowels, as has occurred in environments with strong right-edge vowels, consistent with predictions of Blevins (2008) based on historical sound change in languages that show non-contrastive glottal epenthesis. We have also suggested above that strengthening of the boundary between words may be beneficial above and beyond vowel hiatus contexts for speakers from ethnolinguistically diverse areas, although we leave this suggestion to further studies to examine more closely.

A further point of interest is that we observed a small (but nonetheless substantial) number of items in which alternative strategies were used to resolve hiatus, in addition to glottalisation and liaison: namely, elision of the right-edge vowel and true hiatus. With the exception of one case of elision, all of these were produced in the linking-r context by speakers in the diverse and super-diverse groups, with the majority produced by speakers in the super-diverse group, and in the prosodic environment containing a weak $V_2$ (e.g. *her alarm*, *four o'clock*). Note that this is the environment in which linking-r occurred most frequently overall, but in which the diverse and super diverse groups showed increased use of glottalisation. Thus, it would seem that use of linking-r (i.e. the traditional hiatus resolution strategy) is not only being reduced in favour of glottalisation, but is also being substituted with other strategies in linguistically diverse areas. While the use of elision and true hiatus may appear incompatible with that of regularisation towards glottalisation, it is possible that this may represent an interim stage between the two dominant strategies, and may be an indication of greater instability in the hiatus system for speakers from ethnolinguistically diverse areas. Alternatively, the greater tolerance of true hiatus and elision may be due to crosslinguistic influences or transfer. Ultimately, a systematic analysis is difficult with only a small number of items in each of these categories. However, the presence of these hitherto unreported realisations in AusE demonstrates the rich variation that is present in such linguistically diverse communities.

We acknowledge that the data examined in this study were produced in a controlled, formal task. This approach was necessary to ensure we had a consistent set of hiatus contexts sampled across a large number of participants. Nonetheless, due to the nature of the task, a limitation of this study is that the results observed here may not generalise to more naturalistic, spontaneous speech. A further limitation of this study is that, despite examining a range of contexts in which hiatus is resolved, this was not exhaustive in that not all possible hiatus contexts were included. For example, we have not examined intrusive-r, and neither have we examined whether other possible weak vowels (such as the happY vowel) in $V_1$ position show similar effects to the weak vowels examined here. A possible future direction for this work, then, is an analysis of the full set of possible hiatus contexts in a large corpus of spontaneous speech. As mentioned above, it is possible that speakers' particular language backgrounds may influence whether hiatus is more or less likely to be resolved through glottalisation, at least in the early stages of change before diffusion into the greater community occurs. Although an examination of the participants' various language backgrounds was beyond the scope of this paper, studies from the L2 acquisition literature suggest that some languages may show a greater tendency towards the use of glottalisation than others (e.g. Lleó and Vogel 2004; Schwartz 2016). Another possible extension to this study may therefore be to examine language specific differences in the use of glottalisation as a hiatus breaking strategy within a linguistically diverse community.

## 6 Conclusions

This study analysed hiatus resolution in AusE and the effects of prosodic strength and linguistic diversity on its realisation in a set of carefully controlled elicited phrases. Consistent with prior studies, we have shown that glottalisation is the most common strategy for resolving hiatus when the right-edge vowel is strong (i.e. at the foot boundary), whereas liaison (linking-r or gliding) is generally restricted to weak $V_2$ contexts. In addition, we found that $V_1$ strength affects the likelihood of glottalisation occurring in weak $V_2$ contexts, with more glottalisation occurring when $V_1$ is weak (WW) (i.e. between unfooted syllables), than when $V_1$ is strong (SW) and therefore within the trochaic foot, highlighting the very close connection between the syllables within the foot. Furthermore, we have shown that glottalisation and liaison pattern differently in linking-r and gliding contexts, with glottalisation less likely to occur in gliding contexts, which may point towards linking-r and gliding surfacing due to different processes.

The use of glottalisation to resolve hiatus is a change in progress in AusE, and the results presented here suggest that speakers from areas with high levels of ethnolinguistic diversity may be driving this change, with increased glottalisation in all prosodic contexts. In addition to increased glottalisation, we also observed alternative hiatus resolution strategies in speakers from ethnolinguistically diverse areas, that may suggest a level of instability in the system of hiatus breaking in areas with high language contact. These changes to the resolution of hiatus and the marking of prosodic boundaries provide an example of how English in Sydney is undergoing rapid structural change as a result of mass language and dialect contact. Future work can examine the extent to which these changes diffuse to varieties of AusE spoken in non-diverse and non-urban areas.

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**Ethics:** This research project was approved by the Macquarie University Faculty of Medicine, Health, and Human Sciences Ethics Subcommittee (Ref: 52019584610860) and the New South Wales Department of Education State Education Research Applications Process (Ref: SERAP2019432). Informed written consent was provided by a parent of each participant and by the participants themselves prior to data collection.
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# Appendix

**Table 6:** Hiatus contexts (linking-r and gliding) model summary.

| | Estimate | SE | *z* | *p* | |
|---|---|---|---|---|---|
| (Intercept) | −1.3535 | 0.3441 | −3.933 | <0.0001 | *** |
| Rhoticity score | −0.2343 | 0.1386 | −1.691 | 0.09091 | . |
| $V_2$ strength (weak) | 3.8611 | 0.5031 | 7.675 | <0.0001 | *** |
| Diversity group (diverse) | −1.2888 | 0.4193 | −3.074 | 0.00212 | ** |
| Diversity group (superdiverse) | −0.421 | 0.4019 | −1.048 | 0.29485 | |
| Hiatus context (*r*) | −1.5017 | 0.2954 | −5.083 | <0.0001 | *** |
| Hiatus context (*w*) | −0.3368 | 0.2583 | −1.304 | 0.19229 | |
| $V_2$ strength (weak): diversity group (diverse) | 0.5845 | 0.4557 | 1.283 | 0.19957 | |
| $V_2$ strength (weak): diversity group (superdiverse) | −0.3383 | 0.422 | −0.802 | 0.42274 | |
| $V_2$ strength (weak): preclinkr | 0.7709 | 0.4499 | 1.714 | 0.08661 | |
| $V_2$s trength (weak): hiatus context (*w*) | 0.4095 | 0.4463 | 0.918 | 0.35882 | |
| Diversity group (diverse): hiatus context (*r*) | −1.1949 | 0.6698 | −1.784 | 0.07445 | |
| Diversity group (superdiverse): hiatus context (r) | −0.6573 | 0.4406 | −1.492 | 0.13581 | |
| Diversity group (diverse): hiatus context (*w*) | −0.1343 | 0.3946 | −0.34 | 0.7336 | |
| Diversity group (superdiverse): hiatus context (*w*) | −0.6399 | 0.3584 | −1.785 | 0.07422 | |
| $V_2$ strength (weak): diversity group (diverse): hiatus context (*r*) | 0.6697 | 0.7989 | 0.838 | 0.4019 | |
| $V_2$ strength (weak): diversity group (superdiverse): hiatus context (*r*) | 0.1254 | 0.6077 | 0.206 | 0.8365 | |
| $V_2$ strength (weak): diversity group (diverse): hiatus context (*w*) | −0.4069 | 0.6049 | −0.673 | 0.50114 | |
| $V_2$ strength (weak): diversity group (superdiverse): hiatus context (*w*) | 0.2231 | 0.5688 | 0.392 | 0.69492 | |

Asterisks represent significant effects: * = < 0.05; ** = < 0.01; *** = < 0.001.

**Table 7:** Linking-r model summary.

| | Estimate | SE | *Z* | *p* | |
|---|---|---|---|---|---|
| (Intercept) | −2.47 | 0.32 | −7.63 | <0.0001 | *** |
| Rhoticity score | −0.12 | 0.14 | −0.87 | 0.38438 | |
| $V_2$ strength (weak) | 4.15 | 0.36 | 11.37 | <0.0001 | *** |
| Diversity group (diverse) | −2.73 | 0.70 | −3.89 | <0.0001 | *** |
| Diversity group (superdiverse) | −1.18 | 0.48 | −2.47 | 0.0135 | * |
| $V_1$ strength (weak) | −0.67 | 0.35 | −1.90 | 0.05756 | |
| $V_2$ strength (weak): diversity group (diverse) | 1.60 | 0.72 | 2.23 | 0.02576 | * |
| $V_2$ strength (weak): diversity group (superdiverse) | −0.09 | 0.49 | −0.17 | 0.86184 | |
| $V_2$ strength (weak): $V_1$ strength (weak) | −0.14 | 0.48 | −0.29 | 0.77243 | |
| Diversity group (diverse): $V_1$ strength (weak) | 2.26 | 0.75 | 2.99 | 0.00279 | ** |
| Diversity group (superdiverse): $V_1$ strength (weak) | −0.53 | 0.68 | −0.77 | 0.43892 | |
| $V_2$ strength (weak): diversity group (diverse): $V_1$ strength (weak) | −2.04 | 0.86 | −2.36 | 0.01811 | * |
| $V_2$ strength (weak): diversity group (superdiverse): $V_1$ strength (weak) | 0.74 | 0.80 | 0.93 | 0.35434 | |

Asterisks represent significant effects: * = < 0.05; ** = < 0.01; *** = < 0.001.

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