Anticipatory planning of r-insertion in Australian English

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ABSTRACT

In non-rhotic Australian English, glottalization and 'r' insertion are strategies used to separate contiguous heterosyllabic vowels (hiatus). This study examined hiatus breaking strategies to determine whether realisation and incidence differed as a function of prosodic context. We were also interested in whether inserted 'r' exhibited pre-planning. In an elicited production task, 14 non-rhotic Australian English speakers produced sentences containing two types of coda-less monosyllabic target noun (e.g. *paw* - containing no orthographic 'r', and *door* - containing orthographic 'r'). These were followed by an onset-less preposition (*of, under, above*) (e.g., 'This is the *paw of* the dog'). The incidence of inserted 'r' did not vary significantly across prosodically controlled but orthographically different contexts. However, the nature of the following preposition affected the choice of 'r' vs. glottalization. Importantly, for those speakers who produced auditorily identified 'r', we observed anticipatory F3 lowering in the vowel preceding inserted 'r' indicating non-local planning.

Keywords: r-insertion, speech planning, Australian English, glottalization, hiatus.

1. INTRODUCTION

Hiatus occurs across word boundaries and within words when a coda-less syllable is followed by an onset-less syllable (e.g. *four eyes, drawing*) resulting in V.V adjacency. As hiatus is a dis-preferred phonological context in English, a range of strategies can be adopted to remove vowel adjacency, such as glottalization or consonant insertion [1]. In non-rhotic varieties of English such as Australian English (AusE), it is common for /ɹ/ to intervene to break up the adjacent vowels within a phonological phrase when the first vowel is non-high [4]. The intervening /ɹ/ is typically labelled as linking 'r' if etymologically justified (e.g. *sore eyes*) or intrusive 'r' if not (e.g. *saw eyes*) [7, 9, 13]. Several studies have found a greater incidence of linking than intrusive 'r', presumably based on orthographically motivated resistance [10, 11]. In this paper we adopt the term *insertion* rather than epenthesis to characterise both linking and intrusive 'r' as there is no clear evidence for determining if hiatus breaking 'r' has an underlying lexical representation or not.

Other facilitatory phonological conditioning factors for inserted 'r' include the absence of a prosodic boundary [6], a metrically weak vowel at the right edge of hiatus [4, 5] and local increased speech rate [4]. In a corpus-based study of read speech, Cox et al. [4] found that the presence of a foot boundary identified by a metrically strong vowel on the right edge inhibited inserted 'r'. This raises questions about the use of r-insertion and glottalization as a function of prosodic strength of the second vowel in hiatus (i.e. whether the second vowel is a weak vowel such as a schwa or not), and proximity of the hiatus to a foot boundary.

The possibility of r-insertion raises questions about planning of the intervening rhotic sound. Do speakers look ahead to the hiatus during speech planning before speech is initiated, or is inserted 'r' simply an articulatory interpolation from one vowel to the next? As Whalen [14] showed, co-articulation is related to planning. He observed anticipatory co-articulation in a nonsense V_1CV_2 string when V_2 was known; however, the effect disappeared when V_2 was not known before speech began. The most important acoustic feature of /ɹ/ (retroflex or bunched), is the low F3 [5, 12, 15]. In studying co-articulation in a V_1CrV_2 sequence in American English, Boyce and Espy-Wilson [2] reported some degree of anticipatory F3 lowering at the syllable peak in V_1. This raised the possibility of anticipatory F3 lowering if r-insertion was planned. Speakers who look ahead to an upcoming hiatus could plan to insert an intervening /ɹ/ to break up two contiguous vowels, triggering anticipatory co-articulation at the beginning of the vowel.

The first goal of this study was to investigate the relationship between r-insertion and glottalization as a function of the prosodic strength of the right-edge vowel, proximity to the foot boundary, and orthographic environments. The second goal was to investigate planning of r-insertion by examining F3 at onset of the left-edge vowel preceding the intervening rhotic element.

2. METHODOLOGY

The experiment investigated the use of 'r' and glottalization as hiatus-breaking strategies through an elicited production task. The experiment consisted of a familiarisation phase and a test phase. During the familiarisation phase, three examples of the task were presented. Each example consisted of three pictures presented successively along with an associated auditory prompt featuring the pre-recorded voice of a female AusE-speaking adult. For example, *This is a gate*, *This is a pool*, *This is the gate of the pool*. Participants were then asked to produce the three sentences in successive order without the auditory prompt when the corresponding series of pictures appeared on the computer screen.

During the test phase, the triplet of pictures was presented in successive order without any auditory prompt. The trials were pseudo-randomised and presented in the same order to all participants, with two repetitions. The experiment was conducted by a female AusE-speaking adult to minimize any potential confound from inter-speaker adaptation. Audio recordings were collected in Audacity at a sampling rate of 44.1KHz.

2.1. Participants

Twenty-two AusE-speaking adult participants were recruited from the Sydney area. Eight were excluded to control for language background (one for failing to supply language background information and seven for non-AusE-speaking parentage). Data from the remaining 14 speakers were analysed. All were female students with a mean age of 21.9 years (range 19 to 33 years).

2.2. Stimuli

The test words containing the word-final (left-edge) vowel /oː/ were *door*, *floor*, *paw* and *claw*. In non-rhotic AusE, /ɹ/ would only manifest in these words when followed by a vowel (i.e. an onset-less syllable). Any inserted manifestations of 'r' in *door* and *floor* are considered linking; whereas in *paw* and *claw* the 'r' is considered intrusive.

Three adjacent right-edge vowel contexts were established using the prepositions: *of*, *above* and *under*, as shown in Table 1. These vowel contexts were selected to manipulate the weak vs. strong vowels at the right edge of the hiatus. The word-initial vowel in the prepositions *of* and *above* is a schwa vowel (weak); whereas that in the preposition *under* is a strong vowel. In addition, we manipulated proximity to foot boundary containing the weak vowel. In *above*, the foot containing the hiatus consisted of a strong syllable and one weak syllable (e.g. /ˈpoː ə ˈbɐv ðə/); whereas in *of*, the foot consisted of a strong syllable and two weak syllables (e.g. /ˈpoː əv ðə/). In *under* the hiatus straddles the foot boundary (e.g. /ˈpoː ˈɐndə ðə/). Three different semantically appropriate prepositional phrase complements associated with each target noun were constructed. This generated 36 test sentences (4 test words x 3 prepositions x 3 complements per test word) which were repeated twice, yielding 72 sentences per speaker (total 1008 items). Recall that speakers were required to produce 3 sentences per set. For example, *This is a paw*, *This is a cat*, *This is the paw of the cat.* Note that the first sentence in the triplet provides a control, e.g. *This is a paw*. This first item of each triplet allowed us to ensure that participants did not realize a rhotic in pre-pausal position of the target noun. Speakers were encouraged to accent the phrase final noun.

Table 1: Stimuli.

contexts			
linking	*door* *floor*	*of* *above* *under*	bus/car/church barn/boat/house
intrusive	*paw* *claw*		cat/dog/fox bear/bird/crab

2.3. Coding and Analysis

Both perceptual and acoustic coding were performed on the data.

2.3.1. Perceptual Coding

A phonetically trained female AusE-speaking adult listened to the recordings and coded the data for two properties: (1) presence vs. absence of inserted /ɹ/, (2) presence vs. absence of glottalization.

Twenty percent of the data from the 14 speakers were randomly selected and recoded for reliability. Reliability for the presence of /ɹ/ reached 97%, and for the presence of glottalization reached 93 %.

2.3.2. Acoustic Analysis

The control and test sentences were then subjected to acoustic annotation using Praat. The control sentences (This is a X) contained the test words with word-final /oː/ in phrase-final position. The test sentences (This is the X *of/above/under* the Noun) contained the test words in the hiatus context.

A subset of 8 speakers was selected for further acoustic analysis. Only the test sentences containing *paw* and *door* were used to minimize any potential effect of the lateral consonant /l/ which occurs in

claw and *floor*. This resulted in 244 items available for the acoustic analysis.

In the control sentences (containing the phrase final test noun), the onset and offset of voicing and F2 were used to locate the onset and offset of /oː/.

In the test sentences, the annotated interval (V_V) consisted of the word-final vowel in *paw*/*door*, any intervening rhotic or glottalization and the first vowel of the following preposition. The criteria of F2 and voicing were used to locate the onset and offset of the V_V interval.

F3 values were then extracted from a 50ms window from the onset of /oː/ in both the control and test items and compared for any evidence of coarticulation with a following 'r', as evidenced by a lowering of F3.

2.4. Predictions

According to [10, 11], we expected greater use of r-insertion in the linking than the intrusive environment. On the basis of [4], we predicted r-insertion to occur more frequently with an upcoming weak schwa vowel, and glottalization to occur more frequently with a strong vowel. We also expected r-insertion to be less likely when closer to the foot boundary. In the case of the two prepositions containing onset schwa (*of*, *above*), we predicted less 'r' insertion in *above* contexts where the foot boundary immediately follows the schwa and more 'r' insertion in *of* contexts where hiatus is further from the foot boundary.

Given [2], anticipatory F3 lowering was hypothesized to manifest at the onset of the left-edge vowel if r-insertion was planned. That is, we expected speakers to initiate F3 lowering in the early portion of the vowel.

3. RESULTS

3.1. Perceptual analysis

The perceptual analysis addressed the following questions: (1) whether orthographic context (i.e. linking vs. intrusive) influences the use of inserted 'r', (2) whether the right-edge vowel context (i.e. schwa or not) influences r-insertion

One hundred and fifty-nine items were excluded, 151 for undesirable prosody. Recall that speakers were encouraged to accent the final noun. Sixty-six items in the linking environment and 85 in the intrusive environment contained pitch-accented prepositions following the test words. The remaining exclusion came from 5 missing items and 3 speech errors. This resulted in a usable set of 849 items (433 items in the linking environment, 416 items in the intrusive environment).

To address the first question, we conducted a Chi-square analysis on the total number of perceived /ɹ/s across the prepositions between the linking and intrusive contexts. Contrary to the prediction, incidence of /ɹ/ did not differ between the two contexts: χ^2 (1, 602) = 3.515, p =.061 (2-sided).

Therefore, we collapsed the data from both contexts to address the second question concerning the prosodic strength of the vowel context and proximity to foot boundary. The Chi-square analysis revealed a statistically significant effect of preposition on /ɹ/ use: χ^2 (2, 602) = 54.465, p < .0001. Consistent with our hypothesis, /ɹ/ appeared more frequently when the following preposition was *of* than the other two prepositions. The preposition *of* contains a schwa vowel. Yet the weak schwa vowel in the preposition *above* did not induce as many instances of r-insertion as that in the preposition *of*. This could be related to proximity to foot boundary. In *above* the foot consisted of the target noun followed by one unstressed syllable. In the case of *of* the foot contains two unstressed syllables and is further away from the potential right-edge of the foot boundary (e.g. *paw of the*). The distribution of use of /ɹ/ as a hiatus-breaking strategy is illustrated in Fig. 1a. This pattern was the same in both linking and intrusive contexts, and consistent across all 14 speakers.

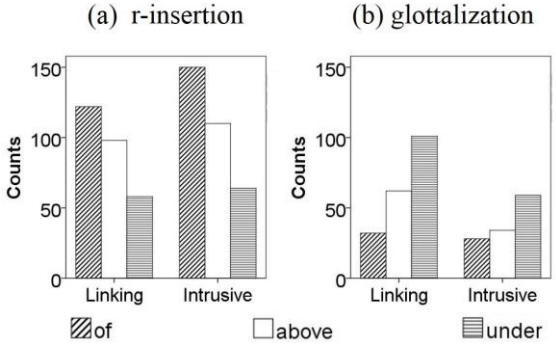

Figure 1: Counts of (a) r-insertion and (b) glottalization preceding the three prepositions in both linking and intrusive contexts.

We also conducted a chi-square analyses on the use of glottalization as another vowel hiatus-breaking strategy. Contrary to the use of 'r', the results revealed a significant difference between the linking and intrusive contexts (χ^2 (1, 316) = 17.329, p <.0001), with more use of glottalization in the linking than the intrusive context. This is illustrated in Fig. 1b.

We therefore examined the effect of right-edge preposition on glottalization in each orthographic environment separately. There was a statistically significant effect of the right-edge preposition in the linking (χ^2 (2, 195) = 36.831, p < .0001) and the

intrusive context (χ^2 (2, 121) = 13.405, p = .001). In both contexts, glottalization was used the least when the following preposition was *of*.

This suggests that the speaker's choice of r-insertion versus glottalization as a hiatus-breaking strategy might be complementary. When 'r' insertion was used most frequently in the *of* context, glottalisation was used the least in the same context. Similarly, when 'r' insertion was used the least in the *under* context, glottalization was used the most in the same context.

3.2. Acoustic analysis

The acoustic results were based on the subset of 244 items from 8 speakers who used r-insertion after *paw* and *door*. We were interested to know if r-insertion was planned and therefore co-articulated with the preceding vowel /oː/. F3 values within the annotated interval were extracted using Praat.

We compared F3 of the vowel /oː/ in the control sentence (*This is a paw*) to that of the corresponding vowel in the test sentence (*This is the paw of the cat*). F3 values were averaged over a time window of 50ms from the onset of the vowel.

We predicted anticipatory co-articulation to manifest in F3 lowering in the test sentence but not in the control sentence, if inserted 'r' was planned. A paired t-test revealed that F3 was significantly different between the control and test sentences in both the linking (t(7) = 4.563, p =.003) and intrusive (t(7) = 5.089, p =.001) contexts, with F3 in the control sentence being higher than that in the test sentence. This is shown in Figure 2. This is consistent with our prediction of anticipatory co-articulation with the inserted 'r'.

However, *paw*/*door* in the control sentence occurred sentence-finally; whereas the same words in the test sentence occurred sentence-medially. To discount the possibility that sentence position might have been responsible for the F3 differences found above, we compared the test word in the control sentence (phrase-final) to the corresponding word in the test sentence (phrase-medial) when glottalization but no inserted 'r' was used as a hiatus-breaking strategy. Six speakers provided the data points for this comparison, because two speakers did not use glottalization as a strategy. No statistical difference was observed in the linking (t(5) = .46, p = .665) and the intrusive (t(5) = .698, p = .516) contexts between the control sentence and the test sentences with glottalization. This provides additional support that the anticipatory co-articulation found in the cases of r-insertion could not be attributed to sentence position effects.

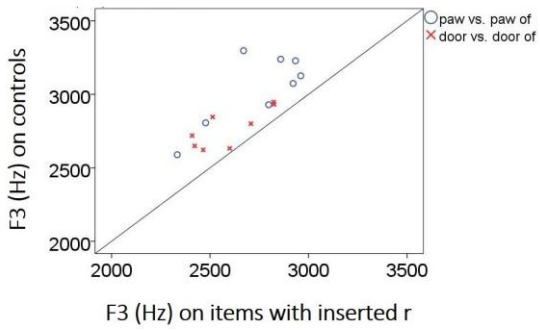

Figure 2: Scatter-plot of Mean F3 values between control items and items containing inserted 'r'.

4. DISCUSSION

The findings show that the orthographic environments did not affect the appearance of r-insertion, reinforcing [3]'s observation that the two types should be modelled as synchronically indistinguishable. However, the type of preposition on the right-edge of the structure did have an effect. The schwa in *of* favoured r-insertion. This result could be due to the fact that this context contained a series of unstressed vowels, triggering maximal incidence of r-insertion. More work is needed to tease apart the relationship between inserted 'r' and prosodic structure.

The perceptual analysis also revealed complementary distribution between r-insertion and glottalization in resolving the hiatus phenomenon. It is surprising that the total observations of glottalization in the intrusive context were fewer than those in the linking context, perhaps suggesting that the former might be inhibiting. Could this be related to social attitude? Or boundary strength? Perhaps phonetic realizations of glottalization reflect different degrees of boundary strength. Further acoustic investigation of perceived glottalization will shed light on this.

When glottalization was used instead of inserted 'r', there was no difference in F3 at the beginning of the left-edge vowel between the control sentence and the test sentence. However, anticipatory F3 lowering was observed in the vowel preceding the inserted 'r'. This suggests that speakers must have looked ahead to the upcoming hiatus in order to plan the execution of /ɹ/ as a hiatus breaking strategy. Since anticipatory coarticulation was found in both the linking and intrusive environments, it is unlikely that the inserted 'r' arises from the influence of the remembered orthographic representation. As anticipatory co-articulation could start as early as the first 50ms of the first vowel, it is unlikely that the inserted 'r' is a local phonetic interpolation between the two vowels in the hiatus context.

5. REFERENCES

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