A DYNAMIC ACOUSTIC VIEW OF REAL-TIME CHANGE IN WORD-FINAL LIQUIDS IN SPONTANEOUS GLASWEGIAN

The Dynamic Liquids Project[i]
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ABSTRACT

This paper investigates the acoustic evidence for real-time change in word-final liquids (/r/ and /l/) in a small-scale study of older male Glaswegian speakers recorded from the 1970s to the 2000s. A dynamic acoustic analysis of the first three formants across the duration of the rhyme (vowel+liquid sequence) shows significant effects of preceding and following phonetic context on the course and trajectories of the formant tracks. We also find raising of F3 for /r/ in speakers who were born and recorded more recently; F2 is lowering for /l/ in the same speakers. Comparison of F2 across the two word-final liquids suggests that /r/ is clearer than /l/ for this Scottish dialect; interestingly the polarity in resonance between /r/ and /l/ is increasing over time.

Keywords: liquids(/r l/), acoustics, sound change, Scottish English, sociophonetics.

1. INTRODUCTION

Liquids, or /r/ and /l/ sounds, are often considered together in terms of synchronic and diachronic description (e.g. [5], [13]). Synchronically, liquids in English accents typically show phonetic variation in auditory resonance, described in terms of 'clearness'/'darkness' ([9],[8],[5]), often with reference to position in the syllable, such that e.g. /l/ is clearer in onset and darker in coda position (e.g.[22],[5]). Differences in resonance can also result in additional layers of contrast in terms of a polarity between /r/ and /l/ [11], for example clear /l/ and dark /r/ in Standard Southern British English and Newcastle English [9],[5], and dark /l/ and clear /r/ in e.g. Manchester and Leeds English [5],[4]. Most previous research has considered nonrhotic varieties, but Carter e.g. [4] analysed two rhotic speakers, one from Northern Ireland and the other from Scotland (Fife), and found that the word-final laterals were darker than the rhotic in the same position. Olive et al [17:222] report clear and dark variants of syllable-final /r/ for American English.

Acoustically, liquids share formants/formant-like structures [23], reflecting cavities arising from the complex sequences of articulatory gestures (e.g.[6]). Darkness is generally associated with lowered F2 for both liquids ([5]). In general, laterals show a lowered first formant and high third formant [12], though if dark, F1 is typically raised. Strongly dark and/or denti-alveolar /l/ shows higher F3 [20]. Rhotics are noted for their heterogeneity in production which is reflected in their acoustic characteristics [15]. Approximant /r/, especially retroflex or bunched productions, are known to show lowered F3, but uvular and dental trills and approximants show high F3 ([15],[12]). American English 'light' /r/ also shows a high/rising F3 [17].

Diachronically, word-final liquids have been observed to show weakening and/or vocalization, for example, the vocalization of postvocalic /r/ in the history of English and other languages [15], and the vocalization of syllable-final /l/ in many varieties of English [13]. Evidence for change is provided by the historical record, and more recently, mainly by auditory phonetic analysis of sociolinguistic survey recordings, even though transcription presents interesting challenges ([24],[7]).

Vernacular Scottish English provides an excellent context for considering synchrony and diachrony in word-final liquids. /l/, a denti-alveolar lateral, is typically very dark [27]; auditory vocalization of /l/ to a high back (un)rounded vowel in syllable-final position has been noted since the 1980s ([25]). /r/ is realized as a range of rhotics, from apical taps to approximants, with occasional rare trills. Sociolinguistic studies since the 1970s, and phonetics manuals and elocution handbooks long before that, have noted the auditory weakening of postvocalic /r/, especially in utterance-final position, and in unstressed syllables such as, e.g. *better* (e.g.[1],[26]). In both cases, the primary evidence for change is auditory, and there has been very little acoustic phonetic investigation, though a small-scale study of Glaswegian suggested that words with weakened /r/ also showed a high/rising F3 [24].

This paper presents the first results of an acoustic investigation of word-final liquids in a real-time sample of Glaswegian. Following [18][16], we use a dynamic acoustic analysis to view variation across the rhyme, over time. Our research questions are:

- What are the dynamic acoustic characteristics of word-final /r/ and /l/ in Glaswegian?

- What evidence is there for acoustic change over real-time in Glaswegian?
- Do Glaswegian word-final liquids show any evidence for polarity in resonance?

2. METHODOLOGY

2.1. Real-time sample of spontaneous Glaswegian

We analysed speech from a real- and apparent-time corpus of spontaneous Glaswegian vernacular, built as part of the Leverhulme Trust funded 'Sounds of the City' project. The electronic LABB-CAT corpus consists of audio recordings with automatically segmented time-aligned transcripts from older, middle-aged and young people made from the 1970s to the 2000s. The recordings are varied in nature, including oral history and sociolinguistic interviews, conversations between friends, and extracts from radio and television. The subset used here is of eight older (67-90 years old) male speakers, two from each decade of recording (1970s, 1980s, 1990s, 2000s), born in the 1890s, 1900s, 1910s, and 1920s.

2.2. Acoustic analysis of /r/ and /l/

The first 35 useable word-final singleton /r/ (e.g. *dear*, *over*) and /l/ (e.g. *well, metal*) tokens were identified for each speaker, resulting in 280 and 283 tokens respectively. We excluded tokens followed by another liquid (e.g. *well right, never liked*). Scots forms showing historical Scots L-vocalization, e.g. *a'* for *all* [2]) were also excluded.

Rather than attempt to isolate the liquid, we followed Plug and Ogden [18] (also Nance [16]), and adopted a parametric analysis. This meant taking formant tracks from across the entire rhyme (so vowel+liquid), allowing us to gain a dynamic perspective for both liquids. Segmentation was carried out using waveforms and spectrograms in Praat [3] as a guide. We labelled the onset of periodicity for the first cycle of the vowel as the beginning of the measurable rhyme. The end of the liquid was determined as the end of visible formant structure, even if this was sometimes weak, and accompanied by some friction [24].

The auditory realization of /r/ was mainly taps and approximants. For this analysis, we took formant tracks for all variants and considered them together. A first pass auditory analysis suggests that taps with a visible interruption in the spectral energy largely occurred in unstressed syllables. This context was included in the statistical modelling, so this variation in formant frequencies (which was generally in the final glottal pulse), is effectively included within 'unstressed' condition. Again, we have not yet carried out a formal auditory analysis of these data; slightly unusually our first view of possible change is acoustic, as opposed to the auditory view of earlier studies.

We used *Formant Edito*r [21] and *Praat* [3] to take a sequence of 11 formant measures at time normalized intervals across the rhyme, and at the same time, to adjust the LPC filter order for speakers and tokens where necessary, and to hand-correct the first three formant tracks (reliable measures for F4 and F5 could not be obtained for many tokens).

Word-final liquids can show substantially weakened amplitude [24]. *Formant Editor* permitted additional tagging to indicate those formant measures with weak energy. This will allow us to carry out a subsequent analysis to take account of the onset and frequency of formants with weakened energy. Here we consider only the formant tracks, noting that recent articulatory work on derhoticised /r/ has shown that the tongue tip gesture may be delayed and still present. What is acoustically weak may still be accessible to the listener [14].

We also coded for preceding and following phonetic environment (e.g. [20]). Given that differently articulated liquids also show different temporal patterns ([22];[14]), but our tracks were time normalised, we also included duration of the rhyme in the statistical analysis.

2.3. Statistical analysis

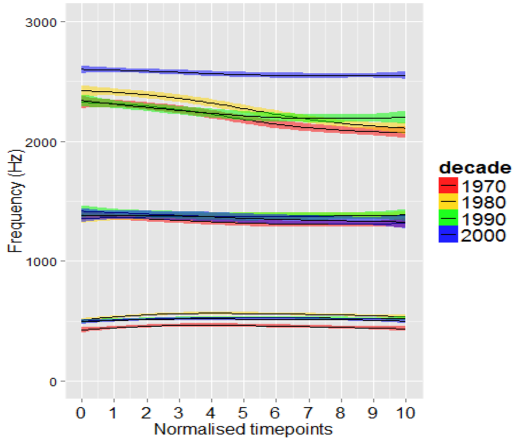
We used linear mixed effects modelling in the lme4 package in R in order to assess whether the formant tracks for F1, F2, and F3 showed overall differences across the rhyme, and/or dynamic differences as the tracks moved into the liquid. To do this, we modelled a continuous factor of normalised timepoints as a fixed effect, and considered its interaction with all possible other factors: preceding vowel front/backness; preceding vowel height/stress; following context; and duration of the rhyme. For /r/ and /l/ we included random intercepts for speaker and word, and a random slope for decade by word, to account for different distributions of words in speakers from different decades. For both liquids, it was not possible to fit the random slope, so intercepts for speaker and word were included.[ii]

It is not possible here to give a formal presentation of the statistical analysis, nor to give more than a few plots. We mention here only results which were significant with $p < 0.05$, and display only those results relating to sound change.

3. RESULTS FOR WORD-FINAL /R/

We found expected effects of phonetic environment [1],[17]. The frontness of the preceding vowel

Figure 1: Time-normalized average formant (Hz) tracks for the first three formants across the rhyme in word-final /r/ in 8 Glaswegian men by decade of recording (0: vowel start; 10 rhotic end)



conditions generally higher F2, whilst F1 rises. When word-final /r/ is followed by a word beginning with a vowel, all three formants rise; when word-final /r/ is utterance final, F2 rises into the rhotic. But the most significant result is found when /r/ occurs in unstressed rhymes, such as *bette<u>r</u>*. In this case, F1 lowers, F2 is kept from dropping, and F3 rises into the rhotic. Only one effect of duration was found: the longer the duration of the rhyme, the lower the third formant overall.

The other highly significant effect influencing the trajectory of F3 was decade of recording/birth (see formant tracks in Figure 1). The predictions from the LME for the significant interaction of normalised timepoint*decade are shown in Figure 2. The value of F3 decreases as the rhyme progresses into the rhotic for all speakers, but especially for those recorded in the 1970s and 1980s. Those recorded in the 1990s, and especially the 2000s, on the other hand, show a much shallower descent, leaving both groups showing F3 values which are much higher for the final points of the rhyme (8-10).

Figure 2: Predictions from LME for the F3 tracks for word-final /r/, showing interaction of decade of recording/birth with normalised timepoint.

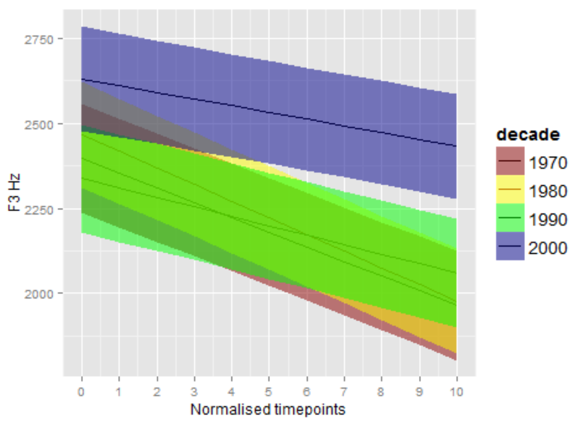
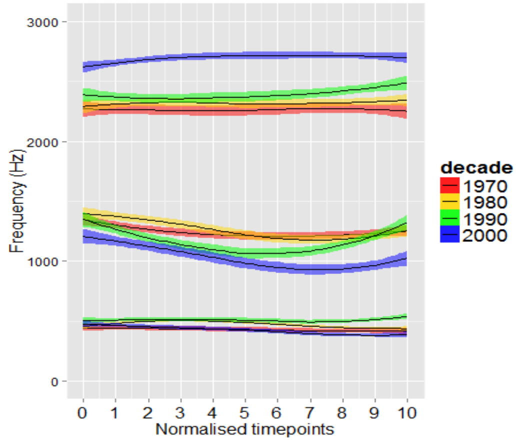


Figure 3: Time-normalized average formant (Hz) tracks for the first three formants across the rhyme in word-final /l/ in 8 Glaswegian men by decade of recording (0: vowel start; 10 rhotic end)

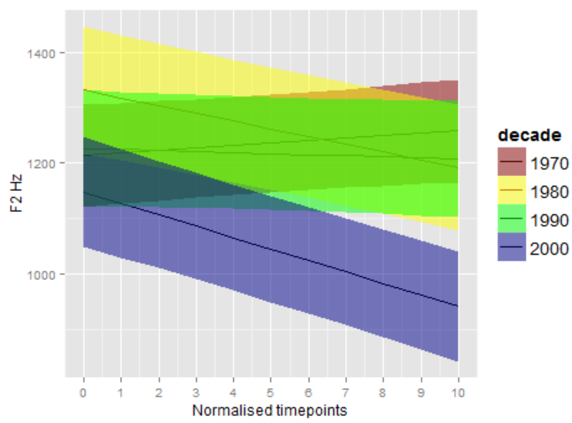


4. RESULTS FOR WORD-FINAL /L/

For word-final /l/, the formant track which shows the main impact of phonetic environment is F2. As expected [20], preceding high, and front, vowels keep the track raised as it moves into the lateral. F2 is also raised into the end of the rhyme when /l/ is utterance final. As the duration of the rhyme increases, the overall values of the F2 and F3 tracks also become substantially higher.

Normalised timepoint*decade of recording is also a highly significant interaction for all three formant tracks for word-final /l/ (see Figure 3). This shows the greatest differentiation for the speakers born in the 2000s, whose first and second formants lower into the lateral, whilst the F3 rises slightly. F1 lowering and F3 raising is also found for those born in the 1990s. F2 lowering is shown by those born in the 1980s. The predictions from the LME for this interaction are shown in Figure 4.

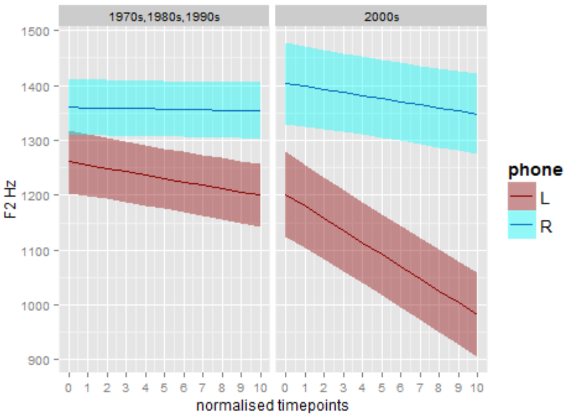
Figure 4: Predictions from LME for the F3 tracks for word-final /l/, showing interaction of decade of recording/birth with normalised timepoint.



5. CHANGE IN WORD-FINAL LIQUIDS

Our final analysis was a direct comparison of the formant tracks for both liquids together. This shows us that /r/ and /l/ are kept distinct across the course of the rhyme for all three formant tracks. This in itself might not seem surprising. We might expect the F1 in the lateral to drop [20] and that of the rhotic to remain stable. We might also expect the F3 in the lateral to rise, and that in the rhotic to drop [23]. But what is interesting is that these effects are found, but also with an interaction with decade of recording, always for the 2000s speakers, and sometimes for the 1990s or 1980s speakers. The acoustic distinction between the two liquids appears to be becoming sharper over time. This is most clearly evidenced in F2 (see Figure 5). /r/ shows a consistently higher F2 than /l/, but the shift to a much lower F2 in /l/ by the 2000s speakers (which begins in the 1980s speakers) means that the difference, and likely additional contrast in resonance, has also been enhanced over time.

Figure 5: Predictions from LME for the F2 tracks for word-final liquids, showing interaction of normalised timepoint with phone and decade of recording (shown as two levels for ease of viewing).



6. DISCUSSION

This small-scale study begins a longer term programme of research into real-time variation and change in liquids in Glaswegian, with an accompanying interest in establishing the evidence for polarity in resonance between /r/ and /l/ in this rhotic dialect. Our aim is at the same time to develop a feasible methodology for investigating liquids in spontaneous speech using reliable dynamic acoustic measures ([18],[16]) which are relatively easy and quick to obtain. Previous sociolinguistic and sociophonetic research charting real- and apparent-time change has largely relied on auditory data (e.g.[26],[24]), which provide an important perspective on what may be happening. We intend to carry out a formal auditory analysis of these data in order to assess the extent to which auditory categories map onto the acoustic results found here, as well as to discover whether including tokens with short periods of spectral discontinuity (some taps and the seven voiceless trills heard in these speakers) alters the acoustic results. (At this stage we suspect it will not, because such taps appear to overlap substantially with the unstressed environment).

At the same time, we are keen to learn more about the changes from the acoustic perspective, given that we gain objective continuous data which are amenable to a range of visualizations and statistical analyses. Using such data we have been able to answer our research questions posed at the outset. Specifically we have found that alongside expected influences of preceding and following phonetic context, we also find evidence consistent with real-time change separately for both /r/ and /l/. And when both liquids are considered together, we also find evidence in the second formant tracks for an acoustic polarity of /l/ (darker) and /r/ (clearer), which is congruent with that of Carter's data for Fife [4]. In addition this polarity appears to be increasing over time.

The change in the appearance of the higher F3 for word-final /r/ is apparent in a shift between those recorded in the 1990s and especially the 2000s (so born in the 1910s and 1920s), and those recorded in the 1980s and 1970s (born in the 1900s and 1890s). This result is congruent with the recent auditory study of postvocalic /r/ in young soldiers recorded during the First World War, who showed around 30% of their variation to be auditorily weak /r/ [1], especially in unstressed syllables such as *better*. The link between high F3 and weak /r/ is hinted at by [24] and demonstrated in a forthcoming controlled laboratory study of articulation-acoustics-audition [2]. It is not yet clear how this shift may be explained in articulatory terms, though we note that dental trills and approximants also have high F3 [15], so the anterior gesture may have become fronter. The same speakers also show darkening of word-final /l/, which is evident in the steeply dropping F2. Raising of F3 could be congruent with strongly dark /l/ with denti-alveolar place [20]; motivation for the lowering of F1 is less clear. It is intriguing that those born in the 1910s, so the decade of the First World War – a time of great activity and industry in Glasgow – are those who show the changes first. Further research with more speakers will enable us to interpret these data more securely.

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[ii] All the models reported here treat normalised timepoint as a linear predictor, which means that they cannot incorporate non-linearities in formant trajectories. Although this is a simplification, preliminary results from generalised additive mixed models suggest that non-linearities do not play a crucial role in our data set.