F2 variation in Newcastle and Leeds English liquid systems

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In this paper we present a production study designed to explore the relationship between three observations which have previously been made about liquids in British English: first, that laterals have prosodically-determined 'clear' (syllable-initial) and 'dark' (syllable-final) variants; second, that some varieties of English have either clear [l] in all positions or dark [l] in all positions; third, that some varieties with clear [l] have dark [r] while some varieties with dark [l] have clear [r] (in broad phonetic transcription). We take F2 as an acoustic correlate of clearness/darkness and report on F2 variation in two representative varieties of British English, one which has clear initial [l] (Newcastle-upon-Tyne) and one with dark initial [l] (Leeds). We show that Newcastle English has higher F2 frequencies in [l] than in [r] and that the reverse pattern is found in Leeds English. These patterns can also be found in adjacent unstressed vowels but not in adjacent stressed vowels. Final [l] in both varieties has a lower F2 than initial [l]. In intervocalic contexts, these F2 distinctions in the liquids are observed in iambic words for both varieties. In trochaic words they are observed for Leeds only, though the vowel effects can be observed in both varieties. We discuss some phonological consequences of these findings.

1 Introduction

This paper aims to add to our knowledge of the acoustics of liquid consonants in English by means of a production study of their phonetic variation as a function of prosodic structure and regional variation. Liquid consonants are particularly of interest for the study of phonological and phonetic constraints. Phonologically, they straddle the border between consonants and vowels (Coleman 1992; Sproat & Fujimura 1993). Phonetically, it has been claimed that they are made up of multiple articulations (see e.g. Alwan, Narayanan & Haker 1997, Narayanan, Alwan & Haker 1997) and may differ depending on prosodic/metrical position (Ward 1931, Abercrombie 1967). In the Articulatory Phonology framework, liquids can be made up of multiple phonological gestures (see e.g. Browman & Goldstein 1995).

There are two liquids in the phonological system of British English: one which is phonetically lateral and one which is phonetically non-lateral. In this paper we follow the convention of calling the phonetically non-lateral liquid 'rhotic'. The liquids pattern as a group in terms of their distribution; for example, they do not occur in the initial position of word-initial clusters, and liquids are the only consonants found in word-final clusters before non-syllabic nasals (e.g. *film*, *kiln*). Varieties of British English differ in part in whether they

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permit the non-lateral liquid to occur in syllable rimes (known as rhotic varieties) or not (nonrhotic varieties). In this paper we focus on nonrhotic varieties.

1.1 'Clear' and 'dark' liquids

English has been described as having prosodically-determined 'clear' (or 'light') and 'dark' variants of the phoneme /l/ (Sweet 1908; Jones 1909, 1947; Ward 1931; Giegerich 1992). Roughly speaking, clear variants occur in syllable onsets; dark variants occur in syllable rimes (see e.g. Sproat & Fujimura 1993). Note that we do not wish to commit ourselves to an analysis in terms of phoneme theory in this paper: for this reason we use square brackets to represent a broad phonetic transcription (i.e. [l] for laterals, [r] for rhotics).

The primary acoustic correlate of the clear/dark resonance distinction in laterals has been taken to be the frequency of F2: clear [l] has a relatively high F2 (and low F1) whereas dark [l] typically has a low F2 (and high F1) (Potter, Kopp & Green 1947; Lehiste 1964; Bladon & Al-Bamerni 1976; Maddieson 1985; Olive, Greenwood & Coleman 1993; Ladefoged & Maddieson 1996; Carter 1999, 2003; Tunley 1999; Heid & Hawkins 2000; Cruttenden 2001; Recasens & Espinosa 2005). Clear and dark variants of rhotics as well as of laterals have been reported in British English (Kelly & Local 1986, 1989) and in American English (Olive et al. 1993: 204, 216). Olive et al. describe dark rhotics in syllable-initial position and clear rhotics in syllable-final position; they take the frequency of F2 to be a correlate of clearness and darkness in rhotics as well as in laterals. The pattern they describe of low F2 frequencies in syllable-initial rhotics and high F2 frequencies in syllable-final rhotics is consistent with other reported American data (Potter et al. 1947, Lehiste 1964) as well as Carter's (2003) British data: laterals are relatively clear syllable-initially and relatively dark syllable-finally, while rhotics are relatively clear syllable-finally and relatively dark syllable-initially.

1.2 Motivation for the study

We report on a study designed to investigate the interaction of variants of liquids with regional varieties and prosodic structure.

There are two distinct approaches to the distribution of clear and dark liquids. A number of studies including Olive et al. (1993), Sproat & Fujimura (1993) and Huffman (1997) discuss the distribution of clear and dark liquids in terms of prosodic (syllable) structure. Other phonological and perceptual studies (Kelly & Local 1986, 1989; Carter 1999, 2003; West 1999, 2000) have investigated the distribution of clear and dark liquids across regional varieties of English. For instance, in their phonological analysis of clear and dark variants of liquids in British English, Kelly & Local propose that there is a polarity effect which involves both of the English liquids such that the regional varieties they investigated have either a clear [l] and a dark [r] or a dark [l] and a clear [r] (at least in intervocalic post-accentual position); they also found concomitant effects in vowels. Long-range effects associated with [l] or [r] have also been reported by Hawkins & Slater (1994), Tunley (1999) and Heid & Hawkins (2000). The relationship between clear and dark variants of liquids and prosodic structure may not be straightforward. For example, many varieties spoken in the north of England (e.g. in Yorkshire and Lancashire) apparently have dark laterals in all positions while other northern varieties (e.g. in Northumberland and Durham) have clear laterals in all positions (e.g. Ward 1931, Wells 1982, Lass 1984, Watt & Milroy 1999). An attenuated distinction between onset and rime laterals has also been reported in varieties of American English (Lass 1984, Keating 1985, Ladefoged & Maddieson 1996).

The picture which the literature presents can be interpreted as a typology of varieties of English in which dialects fall into two groups:

(i) varieties in which prosodic structure plays a role: clear [l] in onsets and dark [l] in rimes
(ii) varieties in which prosodic structure plays no role and in which there may be polarity effects between the liquids: either

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- clear [l] in all positions and (possibly) dark [r] in all positions, or
- dark [l] in all positions and (possibly) clear [r] in all positions.

However, one particular group of British English dialects has been identified which seems to cross these boundaries. RP/Standard Southern British English is canonically identified as having clear onset [l] and dark rime [l] but has also been demonstrated to have the clear [l] ∼ dark [r] pattern (Kelly & Local 1986, Tunley 1999, West 1999, Heid & Hawkins 2000): an [l] ∼ [r] interaction is found in a variety which has positional variants. This raises the question of whether positional variants are also found in varieties which have an [l] ∼ [r] interaction. That is, is it indeed the case that prosodic structure has no effect on the clearness or darkness of liquids in varieties which seem to have all clear [l]s or all dark [l]s? It is possible that prosodic structure could have an effect in some varieties and not in others, since Recasens & Espinosa (2005) show that, for two dialects of Catalan, the one with clear laterals has positional variants whereas the dialect with dark laterals does not. We examine the phonetic detail of liquids in two non-rhotic varieties of English which have been suggested to lack positional variants: Newcastle English (clear [l] in all positions) and Leeds English (dark [l] in all positions).

We will argue that the typology suggested above is inappropriate for the varieties we investigate, which show not only polarity effects in [l] and [r] but also variation associated with prosodic context.

1.3 Hypotheses

We have no reason to doubt the consensus in the literature (Stevens 1998, for example) with regard to F1, F3 and F4 in liquids (relatively high frequencies for the lateral and relatively low frequencies for the non-lateral) and so we make no predictions with respect to these formants. However, we do predict variability in the frequency of F2.

Note that, from here on, we use the term ‘initial’ to mean ‘word-intial’ (and hence, we assume, also syllable-initial) and the term ‘final’ to mean ‘word-final’ (and hence, we assume, also syllable-final). We use the term ‘medial’ to mean ‘word-medial’ (all word-medial liquids in our data are intervocalic). We do not commit *a priori* to any particular syllable affiliation for medial liquids.

We test the following hypotheses:

1. Newcastle English, which has a high F2 frequency in laterals, will have a relatively low F2 frequency in rhotics; Leeds English, which has a low F2 frequency in laterals, will have a relatively high F2 frequency in rhotics; this will hold for initial and medial liquids but not for final liquids (since there is no final [r] in these varieties);
2. Irrespective of whether the initial lateral has a high or low F2, final laterals will have a lower F2 frequency than initial laterals;
3. Differences in F2 associated with the [l] ∼ [r] contrast will also be apparent in adjacent vowels, irrespective of prosodic structure: Newcastle English will have higher F2 in vowels adjacent to [l] than in vowels adjacent to [r]; Leeds English will have lower F2 in vowels adjacent to [l] than in vowels adjacent to [r].

2 Methods

2.1 Materials

Actually-occurring English minimal pairs were set in the frame *It uttered* . . . . Pairs of words were included which differed only in whether they contained a lateral (for one of the pair) or a rhotic (for the other of the pair). Each word included exactly one liquid. The words varied in vocalic context (frontness, backness, height) and prosodic structure, with the liquids in initial, medial – iambic (pre-accentual), trochaic (post-accentual) – or final position. We report on a core dataset of 20 words per speaker, as in tables 1–3.

Table 1 Lexemes with initial liquids (5 tokens each).

	front V		back V	
high V	*lead*	*reed*	*loot*	*root*
low V	*lap*	*rap*	*law*	*raw*

Table 2 Lexemes with medial liquids (5 tokens each). NB: *Bally* rhymes with *valley*.

	trochaic		iambic	
high V	*belly*	*berry*	*believe*	*bereave*
low V	*Bally*	*Barry*	*alight*	*aright*

Table 3 Lexemes with final liquids (5 tokens each).

	front V	back V
high V	*deal*	*tool*
low V	*pal*	*all*

2.2 Speakers

We report on the speech of eight Newcastle speakers and eight Leeds speakers aged 16–18 years: four females and four males from a community college on the outskirts of Newcastle, and four females and four males from a community college on the outskirts of Leeds. None of the speakers reported speech or hearing impediments. All produced appropriately localised varieties of regional English. None of the speakers had phonetic training and none of them was aware of the purpose of the experiments.

2.3 Procedure

2.3.1 Data acquisition

Target words were arranged into randomised lists in combination with 47 dummy filler words and grouped into blocks of ten sentences. We report on data from five different randomisations of the word lists (i.e. a total of 100 tokens per speaker). Data sets were recorded in sound studios via a Sennheiser MD46 microphone onto a Sony TCD-D8 DAT recorder. Recordings were then resampled at 16000 Hz.

2.3.2 Formant frequencies

The ESPS formant tracker was run over each file, tracking F1, F2, F3 and F4 every millisecond with a 25 ms Hamming window and a pre-emphasis of 0.96. LPC order and an expected F0 range were set appropriately for male and female speakers; appropriateness was defined as producing the fewest errors in the estimated formant trajectories as judged by a visual inspection of the estimates overlaid on a wideband spectrogram. Since liquids result in zeros in the acoustic signal, LPC is not always reliable: gross errors in the formant tracking were corrected by hand using wideband spectrograms, DFT spectra and resynthesis of the original signal using the corrected formant trajectories.

For statistical analysis and to provide an approximation to perceptual relevance formant frequencies were transformed into the ERB-rate scale (Glasberg & Moore 1990). For clarity of presentation we transform mean values calculated in ERB-rate back into the Hertz domain.

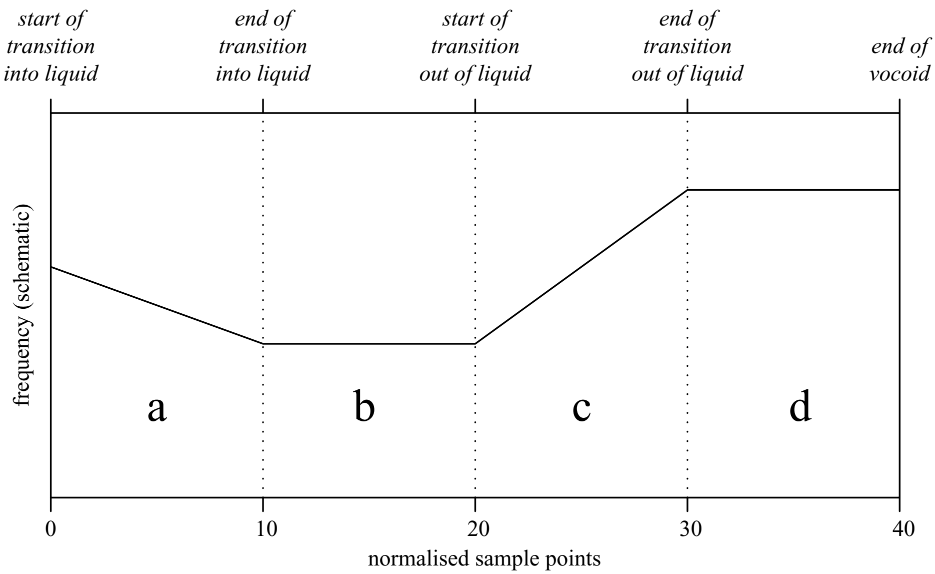

Figure 1 Representation of the labelling of F2 for time-normalisation and analysis. The solid line represents a schematised formant trajectory.

2.3.3 Labelling

Initial, medial and final liquids were hand-labelled using the formant tracks and the xlabel attachment to ESPS/xwaves. Sproat & Fujimura (1993) defined the acoustic onset of laterals in terms of spectral discontinuity or the offset of F2 transitions. We labelled both the onset and the offset of F2 transitions. In order to avoid committing ourselves to an overall segmentation of the liquids we did not use information from elsewhere in the spectrum (such as F1 transitions) except as a guide where F2 transitions were minimal. We labelled

- the start of any vowel preceding a liquid (as defined by the onset of voicing or other spectral discontinuities)
- the start of the F2 transition into the liquid
- the end of the F2 transition into the liquid (i.e. the beginning of an approximately steady state in F2 in the liquid)
- the start of the F2 transition out of the liquid (i.e. the end of an approximately steady state in F2 in the liquid)
- the end of the F2 transition out of the liquid
- the end of any vowel following the liquid (as defined by the offset of voicing or other spectral discontinuities).

2.3.4 Time normalisation

In order to achieve temporal comparability between tokens for acoustic analysis the labels were used as the basis for time normalisation. Figure 1 schematically exemplifies this procedure for initial liquids. Each of the regions (a, b, c, d in figure 1) between each sequential pair of labels was normalised in the time domain by being divided into ten parts of equal duration for a given token, giving 41 sample points in total for each token of initial liquids: ten from the beginning of region a to just before region b (points 0 to 9), ten from the beginning of region b to just before region c (points 10 to 19), ten from the beginning of region c to just before region d (points 20 to 29), ten from the beginning of region d to just before the end of

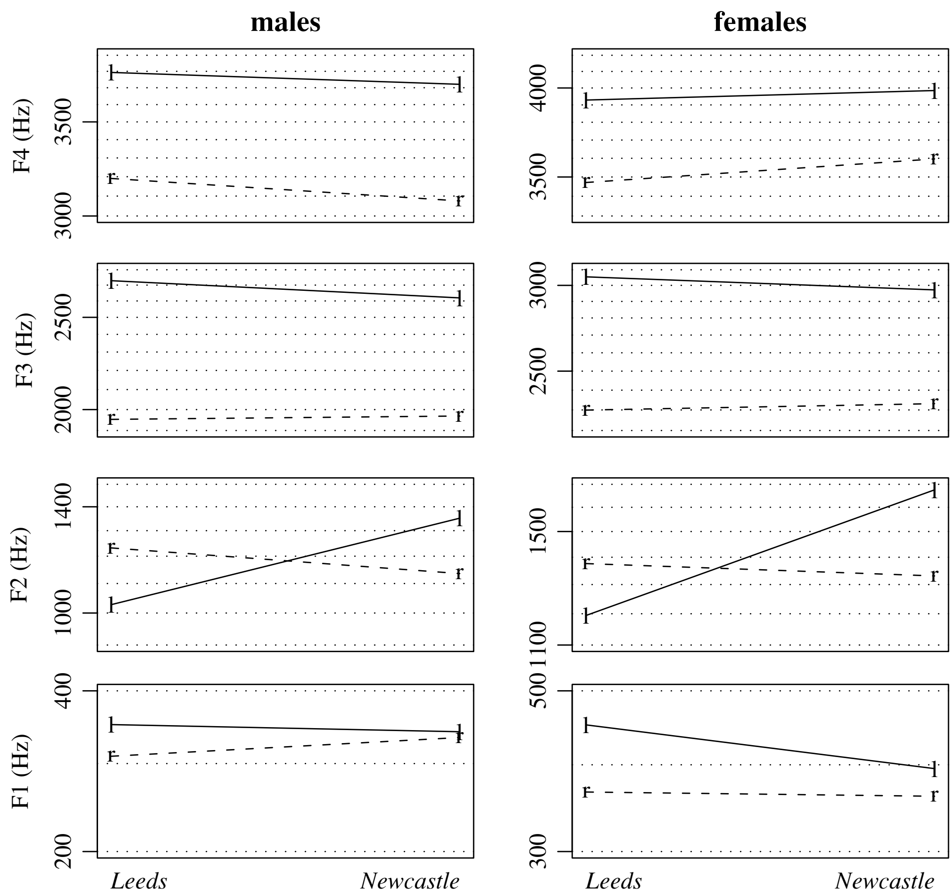

Figure 2 Interaction plots for the mean frequencies of F1–F4 in laterals and rhotics, split by variety. Left panels: male speakers; right panels: female speakers.

the following vowel (points 30 to 39) and one at the end of the following vowel (point 40). Intervocalic liquids have an additional 10 sample points at the beginning (representing the preceding vowel); final liquids have 10 fewer points (since there is a preceding vowel but no transition out of the liquid or following vowel).

3 Results

Spectral characteristics of liquids in the two varieties and across prosodic contexts were compared to determine whether there were consistent differences between the liquids.

3.1 Initial liquids

As a general overview for the purpose of summarising formant frequencies more generally in the liquids, we provide figure 2, an interaction plot showing mean frequencies for the first four formants in initial liquids for both sexes and both varieties.

Repeated measures ANOVAs with variety (Leeds or Newcastle) as a between-subjects factor and liquid identity (lateral or rhotic) as a within-subjects factor showed main effects for

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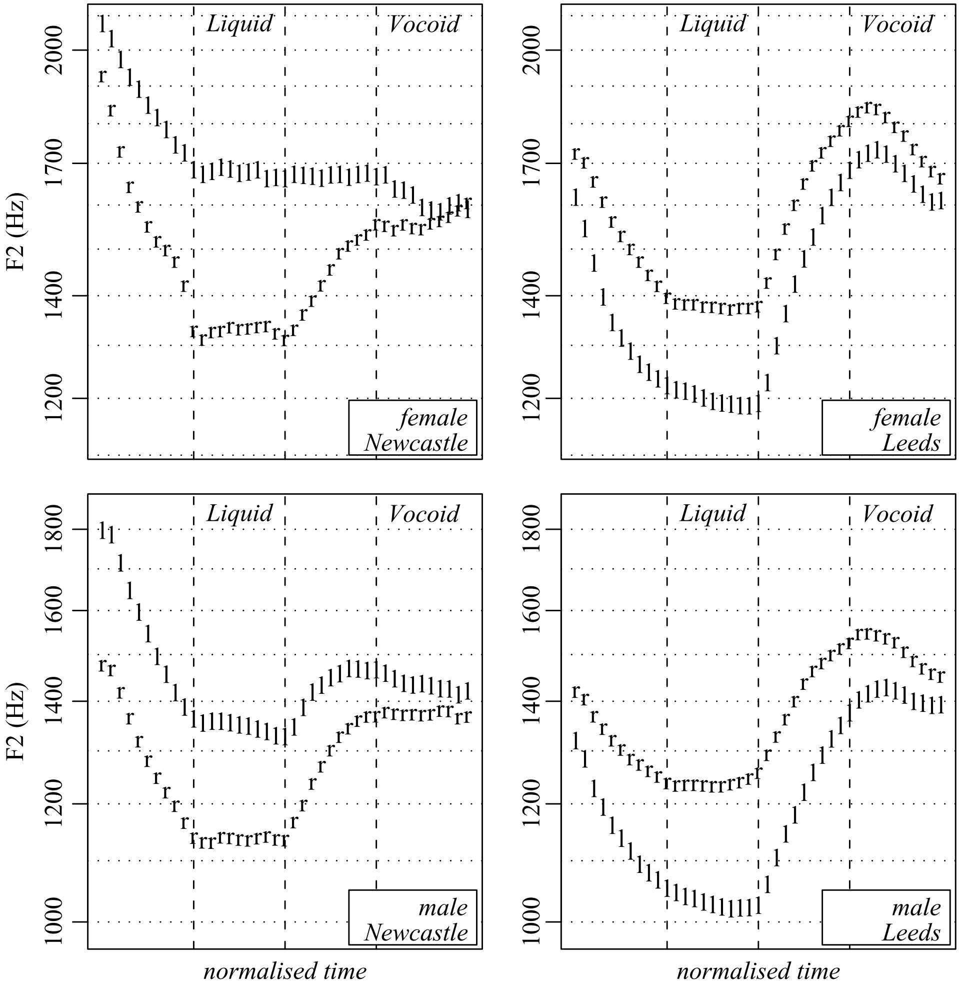

Figure 3 Time-normalised mean frequencies for F2 in initial liquids. Left panels: Newcastle speakers; right panels: Leeds speakers. Upper panels: female speakers; lower panels: male speakers.

liquid identity for both sexes in the F4 and F3 data, and for females only in the F1 data. The female F1 data also showed a small interaction between liquid identity and variety. As for the F2 results (with which we concern ourselves mainly in this paper), there is a small main effect for variety in the female data ($F(1,6) = 8.7195$, $p = 0.0255$) but by far the most outstanding result is an interaction between liquid identity and variety for both sexes: for male speakers, $F(1,6) = 107.9555$, $p < 0.0001$; for female speakers, $F(1,6) = 85.9468$, $p < 0.0001$.

Figure 3 plots mean time-normalised frequencies for F2 in tokens with initial liquids for all speakers. This summary view demonstrates the characteristic F2 patterns for [l] and [r] in the two varieties: for the Newcastle speakers the frequency of F2 is higher in [l] than in [r]; for the Leeds speakers the frequency of F2 is lower in [l] than in [r]. There are other differences between the varieties in figure 3 which we will not examine in this paper, such as the different starting points for the F2 transitions: this reflects the different characteristic unstressed vowel qualities in Newcastle and Leeds English in *uttered* (the word which precedes the target word in the recorded utterances).

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Table 4 Mean frequencies of F1–F4 (in Hz) at the midpoint of the F2 steady state in initial liquids for female and male Newcastle speakers. Values for *t*, *df* and *p* relate to the comparison between laterals and rhotics.

Sex	Formant	[l]	[r]	*t*	*df*	*p*	
female	F4	3985	3597	7.4144	158	< 0.0001	
female	F3	2972	2331	14.231	158	< 0.0001	
female	F2	1675	1331	9.3211	158	< 0.0001	
female	F1	395	362	3.1457	158	0.0020	
male	F4	3721	3075	10.6169	158	< 0.0001	
male	F3	2619	1969	13.2796	158	< 0.0001	
male	F2	1351	1136	5.5923	158	< 0.0001	
male	F1	342	334	0.6141	158	0.54	NS

In the presentation of results which follows, we give the results for the liquids in each variety separately. While the thrust of our paper concerns F2, we begin sections 3.1.1 and 3.1.2 with tables giving more details of the frequencies of the first four formants for initial liquids to demonstrate the general characteristics of the formant frequencies in these varieties.

3.1.1 Newcastle speakers

Table 4 summarises the frequencies of the first four formants at the midpoint of the F2 steady state in initial liquids produced by the Newcastle speakers. These comparisons result from the factors in the ANOVAs reported above and using Bonferroni t-tests as conservative multiple comparisons therefore involves an adjusted alpha value of 0.00625 (i.e. 0.05 divided by the eight possible comparisons).

For female speakers, F1 is higher for [l] than for [r] but there is no significant difference for male speakers. F2 is higher in [l] than in [r] for both male and female speakers. F3 is higher in [l] than in [r] both for males and females. This F3 difference is consistent with the descriptions given by most sources in the literature which indicate that an important acoustic distinction between [l] and [r] is the relatively low F3 associated with the rhotic liquid (Stevens 1998: 535ff.). F4 is higher in [l] than in [r] for male and female speakers. This too is consistent with reports in the literature (Stevens 1998: 535ff.).

In order to check that these midpoint measures are robust, a weighted mean of F2 frequency was calculated over the whole of the liquid steady state by filtering the region through a Hamming window so that each sample point in the steady state portion contributed to the mean value, but the midpoint contributed most. The weighted mean for Newcastle male tokens of [l] is 1348 Hz; the weighted mean for Newcastle male tokens of [r] is 1136 Hz. The weighted mean for Newcastle female tokens of [l] is 1677 Hz; the weighted mean for Newcastle female tokens of [r] is 1327 Hz.

The small apparent differences in mean F2 frequency observable at the midpoint of the vocoid in figure 3 are in fact not significant: $t(158) = 0.7564$, $p = 0.4506$ for male speakers; $t(158) = 0.4793$, $p = 0.6324$ for female speakers.

3.1.2 Leeds speakers

Table 5 summarises the frequencies of the first four formants at the midpoint of the F2 steady state in initial liquids produced by the Leeds speakers.

F1 is higher for [l] than for [r] for both male and female speakers. Unlike the data from Newcastle speakers, F2 for Leeds speakers is lower in [l] than in [r] for both males and females. F3 is higher in [l] than in [r] both for male and female speakers. Similarly F4 is higher in [l] than in [r] for male and female speakers.

The weighted mean F2 frequency for Leeds male tokens of [l] is 1032 Hz; the weighted mean for Leeds male tokens of [r] is 1238 Hz. The weighted mean for Leeds female tokens of [l] is 1200 Hz; the weighted mean for Leeds female tokens of [r] is 1379 Hz. As for the

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Table 5 Mean frequencies of F1–F4 (in Hz) at the midpoint of the F2 steady state in initial liquids for female and male Leeds speakers. Values for *t*, *df* and *p* relate to the comparison between laterals and rhotics.

Sex	Formant	[l]	[r]	*t*	*df*	*p*
female	F4	3928	3471	8.2215	158	< 0.0001
female	F3	3054	2299	15.227	158	< 0.0001
female	F2	1194	1376	7.0352	158	< 0.0001
female	F1	452	367	8.5169	158	< 0.0001
male	F4	3793	3191	14.8803	158	< 0.0001
male	F3	2729	1953	20.3402	158	< 0.0001
male	F2	1028	1232	7.6021	158	< 0.0001
male	F1	351	309	4.9616	158	< 0.0001

Table 6 Mean frequencies of F2 (in Hz) at the midpoint of the F2 steady state in initial and final laterals (Newcastle speakers). Values for *t*, *df* and *p* relate to the comparison between initials and finals.

Sex	Initial [l]	Final [l]	*t*	*df*	*p*
female	1675	1258	10.3199	158	< 0.0001
male	1351	1024	8.4871	158	< 0.0001

Newcastle speakers, the small apparent differences in mean F2 frequency observable at the midpoint of the vocoid in figure 3 are not significant: $t(158) = 1.5661$, $p = 0.1193$ for male speakers; $t(158) = 1.2106$, $p = 0.2278$ for female speakers.

3.1.3 Comparison of varieties

For each variety, the mean frequency of F3 and F4 at the midpoint of the F2 steady state in the liquid is higher for laterals than for rhotics; this is also the case for F1 in most instances. However, while the mean frequency of F2 at the same point is higher for laterals than for rhotics for the Newcastle speakers, the pattern is reversed for Leeds speakers: the mean frequency of F2 is higher for rhotics than for laterals.

Moreover, a comparison between the varieties shows that for male speakers, the mean frequency of F2 is lower in Leeds laterals than in Newcastle laterals ($t(158) = 9.7699$, $p < 0.0001$) whereas the mean frequency of F2 is higher in Leeds rhotics than in Newcastle rhotics ($t(158) = 2.9521$, $p = 0.0036$). The same is true for female speakers with respect to laterals ($t(158) = 16.0941$, $p < 0.0001$). For rhotics, the comparison for female speakers fails to reach the level of statistical significance ($t(158) = 1.3927$, $p = 0.1657$).

3.2 Comparison of initial and final laterals

Repeated measures ANOVAs were calculated for each sex with variety (Leeds or Newcastle) as a between-subjects factor and prosodic position (initial or final) as a within-subjects factor. The results showed main effects for variety ($F(1,6) = 6.3254$, $p = 0.0456$ for males; $F(1,6) = 13.131$, $p = 0.0111$ for females) and prosodic position ($F(1,6) = 46.171$, $p = 0.0005$ for males; $F(1,6) = 22.864$, $p = 0.0031$ for females) and an interaction between the two factors ($F(1,6) = 14.931$, $p = 0.0083$ for males; $F(1,6) = 10.986$, $p = 0.0161$ for females).

Tables 6 and 7 summarise the frequencies of F2 at the midpoint of the F2 steady state in initial and final laterals produced by Newcastle and Leeds speakers respectively. The Bonferroni-adjusted level for alpha is 0.00625.

For both sexes in each variety, the frequency of F2 at the midpoint of the steady state in final laterals is lower than in initial laterals. A comparison between the varieties shows that the mean frequency of F2 is lower in Leeds final laterals than in Newcastle final laterals: $t(158) = 4.1061$, $p < 0.0001$ for female speakers; $t(158) = 2.9002$, $p = 0.0043$ for male speakers. The noticeably

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Table 7 Mean frequencies of F2 (in Hz) at the midpoint of the F2 steady state in initial and final laterals (Leeds speakers). Values for *t*, *df* and *p* relate to the comparison between initials and finals.

Sex	Initial [l]	Final [l]	*t*	*df*	*p*
female	1194	1132	3.0735	158	0.0025
male	1028	950	4.1567	158	< 0.0001

Table 8 Mean frequencies of F2 (in Hz) at the midpoint of the F2 steady state in medial liquids (Newcastle speakers). Values for *t*, *df* and *p* relate to the comparison between laterals and rhotics.

Sex	Metre	[l]	[r]	*t*	*df*	*p*	
female	iambic	1653	1404	7.0444	78	< 0.0001	
female	trochaic	1707	1672	1.0602	78	0.2923	NS
male	iambic	1309	1146	4.4964	78	< 0.0001	
male	trochaic	1313	1361	1.6251	78	0.1082	NS

low F2 in Leeds initial laterals means that they appear to be similar to the final laterals in Newcastle; and indeed these mean F2 frequencies are not statistically distinct: $t(158) = 2.0374$, $p = 0.0433$ (above the adjusted alpha level of 0.00625) for female speakers; $t(158) = 0.1476$, $p = 0.8829$ for male speakers.

3.3 Medial liquids

Repeated measures ANOVAs were calculated for each sex with variety (Leeds or Newcastle) as a between-subjects factor and liquid identity (lateral or rhotic) and prosodic structure (iambic or trochaic) as within-subjects factors showed main effects for liquid identity ($F(1,6) = 38.834$, $p = 0.0008$ for males; $F(1,6) = 17.252$, $p = 0.0060$ for females) and prosodic structure ($F(1,6) = 73.473$, $p = 0.0001$ for males; $F(1,6) = 13.8846$, $p = 0.0098$ for females). As expected, there was an interaction between variety and liquid identity ($F(1,6) = 82.053$, $p = 0.0001$ for males; $F(1,6) = 101.715$, $p < 0.0001$ for females). There was also an interaction between liquid identity and prosodic structure ($F(1,6) = 36.2143$, $p = 0.0009$ for males; $F(1,6) = 19.45$, $p = 0.0045$ for females).

Each of the factors in the ANOVAs has only two levels but the extent of the possible interactions between them means that the Bonferroni-adjusted level for alpha falls to slightly above 0.0010.

3.3.1 Newcastle speakers

Figure 4 contains plots of the time-normalised F2 trajectories for Newcastle speakers in iambic and trochaic words, split by sex of the speaker. Table 8 summarises the data at the midpoint of the F2 steady state of the liquids.

For Newcastle speakers, the F2 distinction observed between initial [l] and initial [r] (see Section 3.1.1) is maintained in iambic structures. At the mid-point of the steady state of F2 in the liquid, F2 is higher in [l] than in [r]. However, in trochaic structures, there is no [l] ~ [r] distinction in F2 at this point. The frequency of F2 at the midpoint of [l] does not vary with the stress pattern. However, F2 at the midpoint of [r] is higher in trochaic structures than in iambic structures, resulting in no distinction from [l] in trochaic structures. For Newcastle male speakers' productions of [l] with different stress patterns, $t(78) = 0.1022$, $p = 0.9188$; for productions of [r] with different stress patterns, $t(78) = 7.5269$, $p < 0.0001$. For Newcastle female speakers' productions of [l] with different stress patterns, $t(78) = 1.5839$, $p = 0.1173$; for productions of [r] with different stress patterns, $t(78) = 7.8442$, $p < 0.0001$.

Tables 9 and 10 present the mean F2 frequency at the midpoint of the vowel preceding and following medial liquids respectively.

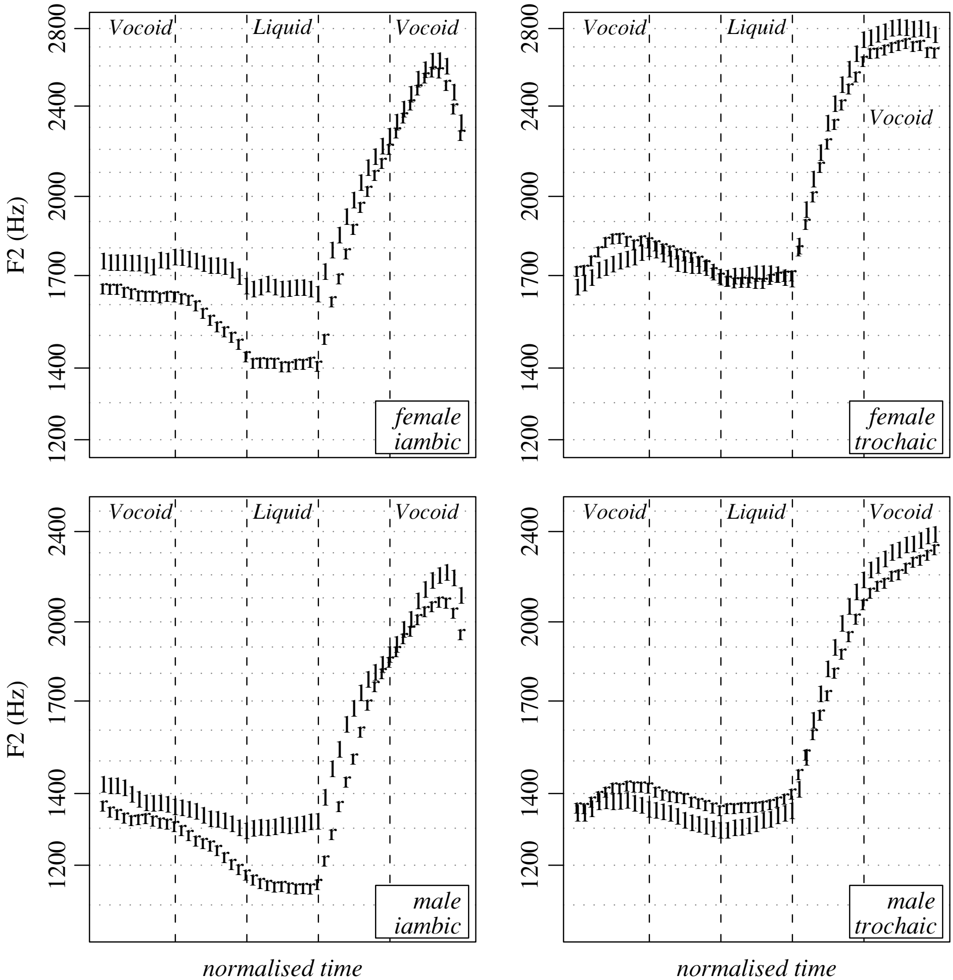

Figure 4 Time-normalised mean frequencies for F2 in medial liquids, Newcastle speakers. Upper panels: female speakers; lower panels: male speakers. Left panels: iambic words; right panels: trochaic words.

Table 9 Mean frequencies of F2 (in Hz) at the midpoint of the vowel preceding medial liquids (Newcastle speakers). Values for *t*, *df* and *p* relate to the comparison between lateral and rhotic contexts.

Sex	Metre	[l]	[r]	*t*	*df*	*p*	
female	iambic	1744	1630	3.8084	78	0.0003	
female	trochaic	1742	1834	2.1483	78	0.0348	NS
male	iambic	1383	1325	2.3686	78	0.0203	NS
male	trochaic	1376	1417	1.0852	78	0.2812	NS

For unstressed vowels in these disyllabic structures, the frequency of F2 at the midpoint of the vowel can be higher in tokens with [l] than in tokens with [r]; this is not the case for stressed vowels.

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Table 10 Mean frequencies of F2 (in Hz) at the midpoint of the vowel following medial liquids (Newcastle speakers). Values for *t*, *df* and *p* relate to the comparison between lateral and rhotic contexts.

Sex	Metre	[l]	[r]	*t*	*df*	*p*	
female	iambic	2581	2540	0.6436	78	0.5217	NS
female	trochaic	2808	2710	2.4706	78	0.0157	NS
male	iambic	2137	2043	1.7111	78	0.0910	NS
male	trochaic	2313	2201	4.208	78	< 0.0001	

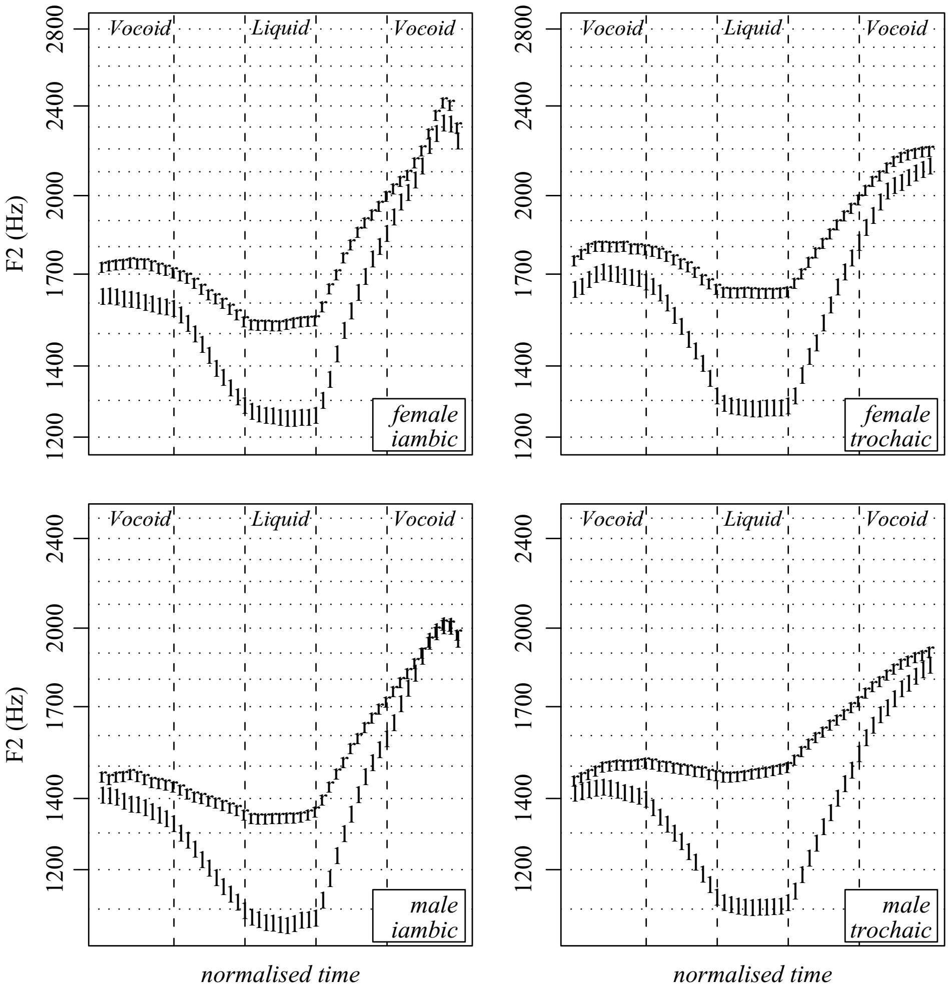

Figure 5 Time-normalised mean frequencies for F2 in medial liquids, Leeds speakers. Upper panels: female speakers; lower panels: male speakers. Left panels: iambic words; right panels: trochaic words.

3.3.2 Leeds speakers

Figure 5 contains plots of the time-normalised F2 trajectories for Leeds speakers in iambic and trochaic words, split by sex of the speaker. Table 11 summarises the data at the midpoint of the F2 steady state of the liquids.

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Table 11 Mean frequencies of F2 (in Hz) at the midpoint of the F2 steady state in medial liquids (Leeds speakers). Values for *t*, *df* and *p* relate to the comparison between laterals and rhotics.

Sex	Metre	[l]	[r]	*t*	*df*	*p*
female	iambic	1252	1526	9.8655	78	< 0.0001
female	trochaic	1276	1635	9.6279	78	< 0.0001
male	iambic	1062	1345	8.0115	78	< 0.0001
male	trochaic	1103	1475	11.2032	78	< 0.0001

Table 12 Mean frequencies of F2 (in Hz) at the midpoint of the vowel preceding medial liquids (Leeds speakers). Values for *t*, *df* and *p* relate to the comparison between lateral and rhotic contexts.

Sex	Metre	[l]	[r]	*t*	*df*	*p*	
female	iambic	1608	1738	3.8673	78	0.0002	
female	trochaic	1703	1799	2.0475	78	0.0440	NS
male	iambic	1381	1470	2.3873	78	0.0194	NS
male	trochaic	1432	1500	1.8183	78	0.0729	NS

Table 13 Mean frequencies of F2 (in Hz) at the midpoint of the vowel following medial liquids (Leeds speakers). Values for *t*, *df* and *p* relate to the comparison between lateral and rhotic contexts.

Sex	Metre	[l]	[r]	*t*	*df*	*p*	
female	iambic	2124	2192	0.7258	78	0.4701	NS
female	trochaic	2041	2145	2.2097	78	0.0301	NS
male	iambic	1888	1900	0.1657	78	0.8688	NS
male	trochaic	1728	1838	2.514	78	0.0140	NS

For Leeds speakers, the distinction between [l] and [r] (see section 3.1.2 above) is maintained in both stress patterns, with the frequency of F2 at the mid-point of the steady state of F2 in the liquid being lower in [l] than in [r] in each case.

As for the Newcastle speakers, F2 at the midpoint of [l] does not vary with the stress pattern. The frequency of F2 at the midpoint of [r] could be interpreted as being higher in trochaic structures than in iambic structures, but statistical significance in the Bonferroni t-tests is not achieved. A higher F2 in [r] in trochees would have the effect of slightly increasing the F2 [l] ~ [r] difference in this respect for Leeds speakers. For Leeds male speakers' productions of [l] with different stress patterns, $t(78) = 1.6031$, $p = 0.1129$; for productions of [r] with different stress patterns, $t(78) = 2.9868$, $p = 0.0038$. For Leeds female speakers' productions of [l] with different stress patterns, $t(78) = 0.9045$, $p = 0.3685$; for productions of [r] with different stress patterns, $t(78) = 2.7396$, $p = 0.0076$.

Tables 12 and 13 present the mean F2 frequency at the midpoint of the vowel preceding and following medial liquids, respectively.

For unstressed vowels in these disyllabic structures, the frequency of F2 at the midpoint of the vowel can be lower in tokens with [l] than in tokens with [r]; this is not the case for stressed vowels.

4 Discussion

We hypothesised in section 1.3 that for the liquid system in different varieties of British English a particular relationship would obtain between the F2 frequency in laterals and the

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F2 frequency in rhotics. This hypothesis is supported in the case of the initial liquids in our data but it requires revision in the case of the medial liquids (which we discuss below).

For each variety studied the two initial liquids are distinct in terms of the frequency of F2. In Newcastle the frequency of F2 in initial laterals is higher than in initial rhotics; in Leeds the frequency of F2 in initial laterals is lower than in initial rhotics. In fact this difference between the varieties holds also for each individual speaker of each variety. For each liquid the two varieties are generally distinct in terms of the frequency of F2. In laterals F2 is higher in Newcastle than in Leeds; in rhotics it is lower in Newcastle than in Leeds.

The Leeds initial laterals in our study appear to be similar to the 'dark' laterals described by Sproat & Fujimura (1993); see also Lehiste (1964). As an example for comparison, Sproat & Fujimura (1993: 299) report F2–F1 measures at the midpoint of [l] with a range from 904.23 Hz to 1315.71 Hz for 'light' (that is, initial in their data) productions and a range of 515.34 Hz to 908.96 Hz for 'dark' (that is, final in their data) productions in high front vowel contexts. In comparison, the range of F2–F1 means (at the midpoint of initial [l] in high front vowel contexts) for the Newcastle speakers in our data set is 1147.98 Hz to 1947.90 Hz for males and 1453.41 Hz to 1980.31 Hz for females. By the same measure, the Leeds male speakers have a range of 568.35 Hz to 821.49 Hz and the Leeds female speakers have a range of 700.34 Hz to 998.45 Hz. While our Newcastle speakers seem to produce initial laterals with a greater F2–F1 distance than Sproat & Fujimura's 'light' initial laterals, our Leeds speakers seem to produce initial laterals which resemble Sproat & Fujimura's 'dark' final laterals.

Additionally, we hypothesised that final laterals would show a positional effect such that F2 would be lower than in initial laterals irrespective of variety. This hypothesis is also supported by our data. The frequency of F2 in final laterals is lower than in initial laterals in a given variety whether or not the F2 frequency in initial laterals is high in comparison with rhotics in the same variety, and whether or not the F2 frequency in initial laterals is high in comparison with laterals of another variety. Thus, in contrast with Recasens & Espinosa's (2005) findings for Majorcan and Valencian dialects of Catalan, our data suggest that the positional effect may be found not only in dialects of English with 'clear' laterals but also in dialects of English with 'dark' laterals, as Recasens, Fontdevila & Espinosa (1995) found in Eastern Catalan.

Is this initial ∼ final effect in laterals evidence that there are indeed two distinct lateral allophones in English? Since we are not committed to phoneme theory, we take it neither as evidence for nor as evidence against the existence of two allophones (in fact, a reviewer points out that, though both varieties have a statistically significant difference in F2 between initial and final laterals, the difference appears greater in Newcastle than in Leeds and that difference in magnitude may influence a decision on whether there are one or two allophones). If F2 equates to clearness or darkness then we cannot argue against a continuum rather than a binary distinction between clear and dark; that is, if [l] is taken as an object somehow independent of the language or variety of a language in which it is found. But we concern ourselves more with how the phonetic data relate to the contrasts within the language (English, in this case); for us, what matters is how laterals are distinguished from rhotics in English: the binary distinction between clear and dark derives from this (phonological) categorial distinction and is applied in a relative sense in any given variety of the language.

If the observed differences between initial and final laterals are due to change which is recent or in progress in these varieties then our data could provide evidence against the notion of pan-Northern dialect levelling which has been proposed at least for some vowels (see e.g. Watt & Milroy 1999) since any Northern standard would presumably not have a distinction between initial and final laterals. A reviewer raises the possibility that our relatively young speakers may have introduced this pattern under the influence of RP/Standard Southern British English but we have no reason to suspect that our speakers are influenced by the standard variety.

We are grateful to a reviewer who points out that our (word-)final laterals are at least potentially also utterance-final. It could be this utterance-finality, rather than word-finality, which is associated with lower F2 in our final laterals, providing a possible explanation for the initial lateral/final lateral differences we find which have not previously been reported for these varieties.

The F2 patterns observed in initial liquids can be reflected in unstressed vowels adjacent to liquids in both varieties, e.g. the first vowel in *believe* or the second vowel in *berry*. They are not found in stressed vowels (whether in monosyllables or disyllables). We assume that the patterns are found in unstressed vowels rather than stressed vowels because of the relatively unconstrained (and possibly targetless) nature of the phonetic interpretation of unstressed vowels (e.g. Browman & Goldstein 1992). This might suggest a phonetic explanation in terms of coarticulation. However, a coarticulation account of the phenomenon is not entirely satisfactory since the F2 patterns are not observed in all cases within the steady state of the liquid itself. In particular, there is no observable F2 difference between [l] and [r] at the midpoint of the liquid steady state in the case of trochaic structures produced by the Newcastle speakers, yet the following unstressed vowels display the predicted F2 relationships, at least for the male speakers. A straightforward account of this phenomenon would be to consider it as a case of a local phonological contrast with distributed phonetic correlates (see for example Heid & Hawkins 2000, Coleman 2003, Hawkins 2003, Local 2003).

At first glance the data suggest that Leeds medial liquids are not sensitive to metrical structure: the [l] ~ [r] F2 pattern observed in word-initial onsets of strong syllables is preserved both in medial onsets of strong syllables (iambs) and in medial onsets of weak syllables (trochees), assuming medial liquids are affiliated with syllable onsets. Conversely, Newcastle medial liquids do appear to be sensitive to this metrical difference: in onsets of strong syllables the word-initial pattern is preserved while in onsets of weak syllables it is absent, again assuming medial liquids to be affiliated with syllable onsets. In fact the data show that in both varieties, F2 does not vary for [l] across onsets of strong versus weak syllables whereas the frequency of F2 in [r] can vary and, where it does vary, it is higher in onsets of weak syllables than in onsets of strong syllables.

A phonological theory in which all medial liquids are syllabified simply as onsets (with no further metrical distinction such as strong versus weak) would predict non-varying [l] and non-varying [r] across iambs and trochees. An alternative account with coda capture (Kahn 1980) might permit two syllabifications for [l]: one into the rime (where the strong syllable is maximised in trochees) and one into the onset (where the strong syllable is maximised in iambs). This approach (or, indeed, one incorporating strong and weak onsets) would predict varying [l] (since word-initial and word-final [l] differ, suggesting that syllable-initial and syllable-final [l] might also differ) and non-varying [r] (since in nonrhotic varieties of the kinds we are describing, all instances of [r] would be syllabified into onsets). A third possibility is to analyse these nonrhotic varieties either as lacking phonetic rhotics only in foot-final position (Harris 1994) or as being phonologically rhotic, allowing medial [r] to be syllabified into rimes in trochees. This third approach would allow direct comparisons with data from rhotic varieties in which the frequency of F2 in [r] is indeed higher in rimes than in onsets (see section 1.1 above). However, this would predict varying [l] as well as varying [r].

What is conspicuous by its absence is a straightforward phonological account for the frequency of F2 in [l] not varying and the frequency of F2 in [r] varying across iambs and trochees.

There may be a phonetic account for the acoustic variation we observe in [r] between iambic and trochaic structures. During the recording sessions, we observed that some of our speakers produced tokens of [r] with noticeable labiodental approximation. This was particularly the case for the Newcastle speakers (and the iambic ~ trochaic variation in [r] reaches the level of statistical significance for the Newcastle speakers). We suspect that labiodental productions of [r] in our data may be linked in some way to raised frequencies of F2 but we are not in a position to provide a quantified analysis of the relationship between acoustic data and articulatory variation in this dimension. However, Foulkes & Docherty (2000) have identified a linguistic change in progress with an increased incidence of labiodental tokens of [r] with a concomitant raised F3 in Newcastle English. Their spectrograms exemplifying the difference between labial and non-labial productions of [r] also appear to show a higher F2 in the labial cases. The variability of [r] we observe might be related to this linguistic change in progress.

5 Conclusion

In discussing possible typologies of liquids (section 1.2) we commented that Standard Southern British English has previously been identified as a variety which has an [l] ~ [r] polarity effect as well as the well-known variation between syllable-initial and syllable-final laterals. We have demonstrated that two varieties of British English commonly described as having laterals which are either all clear or all dark actually display phonetic variation correlated with prosodic structure as well as polarity effects between [l] and [r]. Moreover [l] ~ [r] polarities and prosodic contexts interact such that the polarity effects do not occur in all prosodic structures. We have also demonstrated that unstressed vowels adjacent to the liquids can display the polarity effects even where those effects are attenuated in the liquids themselves.

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