An articulatory investigation of word final /l/ and /l/-sandhi in three dialects of English

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ABSTRACT

We use the MOCHA articulatory speech database to explore word-final /l/ in English. Eight speakers, drawn from three nations with distinct phonological systems (Scotland, England and USA) all display pervasive and systematic /l/ vocalisation (defined as lack of alveolar contact in EPG data). Vocalisation of word-final /l/ is radically context-dependent for seven subjects. These English speakers have a post-lexical external sandhi alternation of consonantal vs. vocalic /l/ which appears categorical. We describe the general tendencies and the systematic linguistic differences between speakers, which are orthogonal to national dialect. Coda (re)syllabification of /l/ is not subtle or flexible enough to condition the distribution of vocalisation. Prosodic, segmental and phrasal factors are all required. A preliminary EMA analysis of intracontextual variability reveals both gradient and categorical aspects.

1. WHAT IS ENGLISH /l/?

The phoneme /l/ of English is known to vary widely. There is systematic gradient allophony conditioned by different prosodic contexts, as well as variation in the dialect-specific phonetic targets found in a given context. In general, the sounds labelled as /l/ in English tend to be lateral alveolar approximants in syllable onset position, hence the use of the IPA symbol /l/ and the conventional broad transcription [l]. Other positions are more variable.

The idea that English /l/ has more than one lingual constriction is supported by the articulatory studies of Giles and Moll [1], Sproat and Fujimura [2] and Narayanan et al. [3]. The stronger, more occlusive of these constrictions is due to a midsagittal apical or laminal gesture towards an anterior target, which in some contexts achieves alveolar contact. The edges of the tongue blade are compressed inwards, bringing them away from the upper teeth to create a complex vocal tract airway. /l/ is regarded as an approximant, or highly sonorous consonant even though there is alveolar contact.

The consonantal gesture of alveolar contact is believed to be articulatorily stronger in onset position, and weaker in coda position (and intermediate in ambisyllabic position) [2, 4]. That this may be due to *general* processes of gestural weakening and differential timing in the coda (relative to the more vocalic dorsal articulation) has been defended in previous work which has looked for similarities between /l/ and other consonants [4, 5]. In coda /l/, a greater relative magnitude and relatively earlier timing of the dorsal constriction makes the coda /l/ impressionistically "darker" than onset /l/. The light/dark distinction appears not to be a general syllabic phenomenon, since /r/ and /l/ may have opposite distributions. Local and Carter [6] show that /l/ varies dialectally in: the absolute extent of lightness in onset and coda positions; the magnitude of the difference between them; and the acoustic cues used to convey syllabically-conditioned dark and light /l/.

Some /l/ have no contact at all with the alveolar ridge, and are termed "vocalised", though most studies of vocalisation are impressionistic or acoustic. Giles and Moll's influential articulatory study [1] found that dark /l/ is often articulatorily vocalised in American English, typically in faster speech rates and following low vowels.

A further distinction of syllabic vs. non-syllabic variants of /l/ can also be made [1, 7]. There is evidence that the vocalisation of /l/ is more likely if the /l/ is syllabic [8], but syllabicity as a term varies widely in its application [7]. Phonetic syllabicity is most convincingly demonstrated by word-final /tl/ or /dl/ sequences whose stops are released laterally into an [l] with no intervening schwa-like transition. If there *is* an intermediate schwa, it may be claimed to be "excrescent", i.e. a transition not a segment, enabling the /l/ still to be treated, less convincingly, as syllabic. For non-alveolar contexts (apple), tokens involving a transitory double articulation and no schwa transition provide good evidence for a syllabic /l/. It is hardest to find instrumental evidence to back up the intuition that postvocalic /l/ can be syllabic in a weak syllable (sensual) or following a long vowel (feel).

Toft, in an acoustic study of Southern British English word-final weak /l/ and /n/ [7] found /l/ was phonetically syllabic following /p/, /t/, and /k/ alike (whereas /n/ tended to be syllabic only after coronals.) Toft's study used only subjects who did not impressionistically vocalise.

Using different methods (acoustic, introspective, articulatory, phonological) to identify syllabic /l/ results in competing classifications. This may merely be a methodological problem, though it may possibly reflect a true indeterminacy about syllabicity itself. Either way, it is important to be clear, so in words such as apple, libel, Michael and visual, we classify the word-final /l/ as *potentially* or *structurally* syllabic, leaving open the possibility that we might need to show whether particular tokens are *truly* syllabic (or not) by some other criteria. We will refer to apple and bible etc. as having a "weak" /l/ context, for /l/ is

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in a metrically weak syllable. Word-final /l/ following a full vowel in a lexically stressed syllable (feel, fill, control) is "strong". Either apple or feel might have a syllabic /l/. Our structural classification, though simple, will therefore be augmented if necessary in order to find out in what sense a syllabic /l/ is likely to vocalise.

2. METHOD

The MOCHA (Multi-CHannel Articulatory) database is planned to include 40 speakers of English each reading 460 TIMIT sentences (British version) [9]. In addition to acoustics, simultaneous articulatory channels comprising Carstens EMA, Laryngograph and EPG were recorded. The "Reading" EPG palate provides tongue-palate contact data at 62 normalised positions. The sampling rate of EPG in the QMUC lab is 200Hz. Released data for SW, SS and AS, unchecked data for the others, the list of sentences, and MATLAB analysis tools can be found online at ftp://bell.qmuc.ac.uk.

The subjects analysed here were selected solely on the basis of the availability of data and not on the grounds that they have vocalised /l/. The five English speakers were: SS, SW, near-RP speakers from SE England; AS, a more London speaker with impressionistically obvious vocalised /l/; JW, a near-RP speaker from the north of England; and SK with a slightly more pronounced northern accent. The Scottish speaker FS is typical of west central Scotland (including Glasgow). The two USA speakers JN and AT do not have a strongly regional accent. All are phoneticians and/or speech therapists. The subjects do not have strong non-vernacular speech, but (near-) standard English.

3. ANALYSIS OF VOCALISATION

Word-final /l/ was vocalised by all subjects in at least some contexts, so we decided to focus here on EPG data, in order to quantify the vocalised and non-vocalised variants of word-final /l/ in different environments.

	prepausal	prelabial	prevocalic
strong	13	16	19
weak	12	13	20

Table 1: Distribution of the 93 targets

The corpus was searched for examples of /l/ in different contexts. To ensure that any lingual contact detected was unambiguously due to an /l/ (because we have no phonetically matched controls to permit subtle comparisons), no /l/+lingual consonant environments were examined. Preconsonantal /l/ is therefore /l/ before the labial consonants /mfvpbw/. Prepausal and prevocalic contexts were also examined. Position in sentence varied. Previous vowel and consonantal context was not controlled. Strong and weak /l/ were examined in all three contexts. The distribution of targets is given in Table 1. In all, 738 tokens were measurable (99%). The materials are available online, at http://sls.qmuc.ac.uk/dept/jscobbie/home.htm.

Given EPG evidence of lingual-alveolar contact, it is relatively simple to determine that a consonantal /l/ is present, if there are no other sources of alveolar contacts in the vicinity. There were, however, two main sources of such contacts: bracing of the tongue along the molars; and swallowing or other prepausal nonspeech lingual activity.

Ambiguities due to bracing or a high tongue position were dealt with by ignoring contacts at the edges of the palate (columns 1&8). Consonantal /l/ had to have a contact in the alveolar zone: the middle six columns in the front 3 rows.

Some speakers produced prepausal words followed by contact in the alveolar zone during the post-utterance silence. The EPG onset to these silent contacts was often [l]-like, even if the contact was clearly a nonspeech constriction. We rejected the hypothesis that these silent contacts were due to /l/ for silent contact can also be observed after vowel-final prepausal words. Hence we stipulated that, to count as evidence for consonantal /l/, contact had to be made during the phonation of the prepausal word.

Before presenting the results, we should note that a qualitative check was made on all subjects' word-initial (phrase-initial and intervocalic) /l/. The sample confirmed our expectation that word-initial /l/ was almost invariably consonantal ("C"). Word-medial intervocalic /l/ was also consonantal preceding stress, but following lexical stress some vocalised ("V") forms were found. Word-medial /l/ preceding a labial was almost always vocalised.

All our subjects produced large numbers of word-final /l/ as V, calling into question the idea that vocalisation is stigmatised or rare. The speakers are not homogeneous, however. This may indicate a number of discrete systems of /l/ variation, or gradience in the strength of /l/'s alveolar gesture in different contexts in different systems.

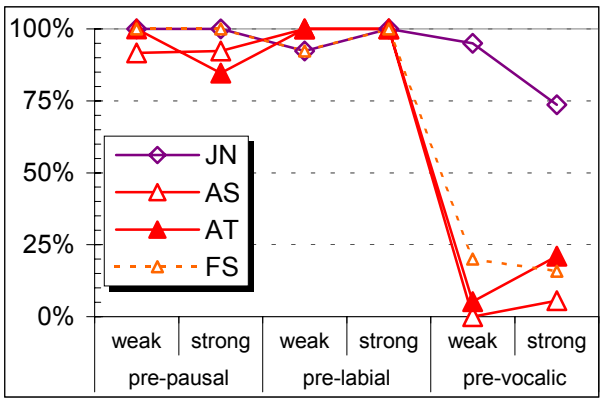

Figure 1: Rate of vocalisation amongst high vocalisers.

Figure 1 presents the more extreme vocalisers, who appear to comprise two groups. JN's word-final /l/ is pretty much V in all contexts. Three speakers (AS, AT and FS) vocalise in both our coda contexts (prepausal and prelabial) but not prevocalically, in an almost categorical way. Prevocalic /l/ could be consonantal due to resyllabification (which stops it being a pure coda), or purely because it is prevocalic.

Figure 2 presents the results for the speakers who cannot be said simply to have V in the coda. JW and SK have a very

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clear split between prepausal and prelabial /l/, and only vocalise before a (labial) consonant. A more complex pattern exists for SS and SW, because there is a difference in the behaviour of final /l/ depending on the prosodic prominence of the syllable in which it appears. In a lexically weak syllable, /l/ is usually vocalised, while in the coda of a strong syllable, /l/ is V more rarely.

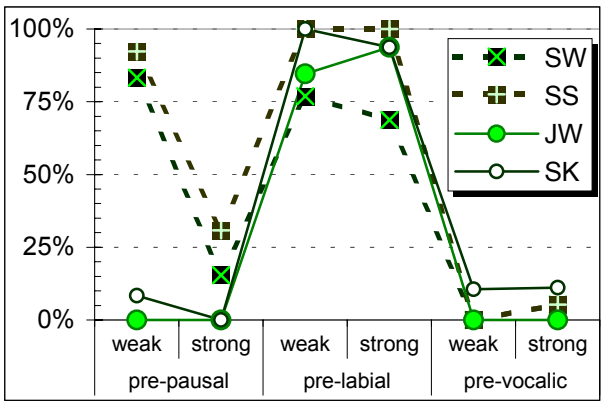

Figure 2: Rate of vocalisation, non-coda vocalisers.

Defining vocalisation using a threshold of contact categorises all /l/ in a binary way. The high/low % values of the results suggest that most subjects do indeed alternate categorically (but not perhaps JN, SW and SS). Even so, it is obvious that EPG does not reveal the extent by which the tongue fails to make anterior contact. The location of the TT EMA coil (located 7-10mm posterior to the tip) provides evidence of the deletion or weakening of the alveolar gesture, and for the allophony being gradient or not.

The MOCHA materials are deliberately heterogeneous and there are no repetitions, so it is hard to analyse subtle intraspeaker variation using gestual paths for example. We can, however, easily find the location of the TT coil (where "horizontal" means "parallel to the upper bite plane"). The annotation point, the speed minimum of /l/ is almost always during the articulatory closure, if there is any.

There is space here only to address the most variable speakers and contexts. JN's strong /l/ when prevocalic is vocalised 74% of the time (Figure 1). Figure 3 shows how similar the mean C and V TT locations are. This suggests that JN's prevocalic /l/ has a single target on the cusp of vocalisation which is sometime C and usually V. The V tokens are only *slightly* vocalised. AT's prevocalic strong /l/ is V 21% of the time, and FS's 16%. For both subjects, the C and V allophones have very similar TT locations (not shown). Such intracontextual variation (revealed by EPG) does not seem to result from large differences in TT position. SW's strong /l/ in a prelabial context is vocalised 69% of the time (Figure 2). Her intracontextual variation, however, has a greater (and probably categorical) distinction between C and V variants than these other cases.

Other particularly variable cases involve weak /l/, or strong /l/ in a prepausal context. Whether /l/ is vocalic or consonantal, neither context provides clear closing and opening gestures around a unique TT speed minimum. Weak /l/ often shows continuous movement, and no target location. Prepausal /l/ can be followed by nonspeech movements. In both cases it is uncertain which TT location to analyse, though in future research we will explore various options.

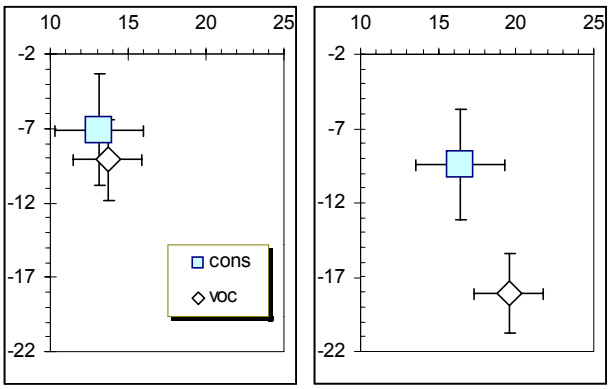

Figure 3: mean TT locations (±1 s.d.) of strong /l/, JN prevocalic (left) and SW prelabial (right). Axes indicate distance (mm) from upper incisor reference coil.

4. DISCUSSION

Borowsky and Horvath [8] have shown that "syllabic" /l/ in Australian English is more likely to be (transcribed as) vocalised than "non-syllabic" /l/. More precisely, weak /l/ (their "Class 1") is more likely to be heard as vocalised than strong /l/ (their "Class 2"). (Class 2 are in turn more likely to sound vocalised than the clustered /l/ in milk or silk, "Class 3".) This first finding is one for which we can provide *some* articulatory support — though in the prepausal context, and for SS and SW only (Figure 2). While SS and SW may be like their Australian speakers, we suspect the majority of our data is more representative. Perhaps the relatively high amount of vocalisation recorded for weak /l/ is due to it being more salient to the listener in that context. Vocalisation is probably being under-reported.

Toft [7] found that (impressionistically consonantal) weak /l/'s syllabicity (acoustically-defined) was *not* conditioned by its leftwards segmental context. Our materials also contain weak /l/ in a variety of postconsonantal and postvocalic contexts, and we found only one possible contextual effect. Prepausal Seattle, which is our *only* example of coda /l/ following /t/ or /d/ (and a proper noun to boot), was *resistant* to vocalisation. AS, SS and SW, who vocalise 32 of 33 other weak /l/, all have a consonantal production of /l/ in Seattle. Moreover, SS and SW (and JW) have [t] laterally released into a truly syllabic [l̩]. AS (and SK) appear to have central release leading to [tˁl̩]. FS, AT and JN vocalise. This suggestive finding reminds us that the most convincing examples of syllabic weak /l/s involve lateral release, in which case the lateral must be consonantal, not vocalic.

Another isolated point of interest concerns JN, whose prevocalic weak /l/ is generally vocalised. It is consonantal only in parental approval, which again suggests /tl/ may not be predisposed to vocalise. There is only one EPG contact; the /l/ is not syllabic. JN vocalises in the only other prevocalic /tl/ (or /dl/): anecdotal evidence.

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Perhaps then, a hypothesis along the lines "syllabic implies vocalic" is oversimplistic. A syllabic weak /l/ may actually be an *alternative* to a vocalised /l/ in contexts phonologically disfavouring consonantal constrictions.

A phonetic account of vocalisation as gestural weakening (undershoot) could bring together the gradience of JN's prevocalic strong /l/ (Figure 3) (which itself may be due to varying hiatus across word boundaries), the weak tendency for vocalisation of weak /l/ to be more common than vocalisation of strong /l/ (SS and SW in Figure 2), and Giles and Moll's finding that vocalisation of strong /l/ is preferred after low vowels and in fast speech [1]. (Giles and Moll found *no vocalised productions of weak /l/*. They asked their subjects to pronounce /l/ as syllabic [l̩] and as non-syllabic [ˀl], so perhaps the task was too artificial.)

A phonetic account based on coarticulation may also be well-placed to link our findings about prelabial /l/ to previous research on /l/ before lingual consonants. Hardcastle and Barry [10] found that in word-final /l/ clusters, vocalisation of /l/ was less common before tautosyllabic coronals than velars. It is difficult to apportion alveolar contacts in a word such as old unambiguously to an /l/, so it may be that mutual lingual coarticulation makes vocalisation less likely. Further, coarticulation could also explain the suggestion above that final /tl/ seems to vocalise less than other weak /l/. It may be that laterally released coronal stops are more resistant to gestural weakenings that affect /l/ generally, because the gestures required for lateral release are simply different to those needed to raise the blade towards the alveolar ridge.

Finally, we note a possible non-syllabic conditioning effect with implications for experimental design: final /l/ was particularly resistant to vocalisation before word-initial /h/. We only have three targets, but FS and JN each vocalise all three, the other subjects produce only 3 vocalised /l/ (17%) between them, though they vocalise 93% of prelabial /l/.

5. CONCLUSIONS

Our articulatory data reveals widespread systematic vocalisation of /l/ among speakers of three non-vernacular varieties of English. The segmental/syllabic context, the phrasal context, and the metrical strength of the word-final /l/ are all relevant. Word final /l/ tends to be vocalised more often in a coda position rather than prevocalically. Considering just the codas, vocalisation occurs more often preconsonantally than prepausally. Considering just prepausal /l/, vocalisation occurs more often if the /l/ is in a weak syllable.

These tendencies are based on speaker-specific patterns. Seven of the eight speakers have a categorical alternation of word-final /l/ in which alveolar contact is conditioned prevocalically but not preconsonantally ("/l/ sandhi"). In addition, prepausal position conditions consonantal /l/ for four of these speakers. Of these, two tend to limit consonantal /l/ to metrically strong codas, while two have consonantal /l/ in both strong and weak syllables.

At a speaker-specific level, most differences in /l/ between different contexts (e.g. prelabial vs. prevocalic) appear categorical. Intracontextual variation is usually small and gradient but may also be categorical (SW in Figure 3). A gestural weakening analysis may be more flexible (and hence preferable to) syllable-based extrinsic allophony, but needs to be able to model the binary nature of most speakers' alternations.

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