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**Dutch rhotic allophony,
coda weakening,
and the
phonetics-phonology
interface**

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Dutch rhotic allophony, coda weakening, and the phonetics-phonology interface

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Abstract

Evidence is presented that suggests that articulation should be considered separately from acoustics (or the auditory impression) in investigations of the interface between phonetics and phonology. We use Ultrasound Tongue Imaging to show that onset and coda versions of Dutch /r/ can have secondary articulations, categorical allophones, and subtle or covert articulations which have few acoustic implications. Covert rhotic (retroflex) articulation was observed in one speaker, who displayed acoustic derhoticisation. We also consider this finding in relation to ongoing work in Scottish English.

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1 Introduction

The phonetics/phonology interface is often approached as a singular and homogenous boundary. However, surface phonological representations have many aspects (e.g. features and segments, phonotactic combinations, metrical structure, intonation), plus there are connected speech processes, all of which interface with phonetics in rather different ways. And cutting across these phonological subcomponents, the phonetic substance of language is twofold, at least. From an articulatory perspective, it comprises speech-motor control and the physiological structure of vocal tract, and these aspects of the interface seem to relate straightforwardly to the concerns of the language user qua speaker. There is also a perspective which is concerned with acoustics and perception, and this relates to the language user qua listener.

One of many difficult areas for the phonology-phonetics interface(s) is the phenomenon of allophony. When some lower unit of structure (typically something equivalent to a segment) appears in two distinct positions in higher structure (typically different roles with the syllable or other prosodic domain, or in different linear relationships to other segments) then the potential arises for phonological allophony. By “phonological”, here, we mean that the representation of the segment in the surface phonological level of representation occurs in two variants, predictably conditioned by categorically-distinct phonological contexts. In addition, “phonetic” allophony refers to the far greater number of cases of predictable contextual differences which exist but which are not thought to be represented by changing the internal phonological content of segments — even though these are still conditioned by categorically-distinct contexts. (We do not include phonetic changes due to nonphonological variations, e.g. in speech rate, or style or affect, in our definition of allophony.)

For a textbook example, in some varieties, English /t/ is often said to be [t^h] in the onset and [ʔ] in the coda and [t] in initial /s/ clusters. It is important to note that the surface level of representation contains all the information required for the necessary translation into the various allophonic variants, whether the relations are phonetic or phonological. What is contentious is, of course, the amount of detail represented in surface structure by virtue of encoding fewer or more allophones: the more allophones are phonological, the more phonetic detail surface structure contains. For recent reviews of different approaches to the content of surface structure and the relationship with different conceptions of the interface, see Pierrhumbert, Beckman and Ladd (2000), Cohn (2006), Scobbie (2007).

We have previously made the criticism of phonology (Scobbie, 2007) that there is no scientific or analytically consistent or agreed means for determining which level of phonetic transcription constitutes the raw data for phonological analysis. It seems sometimes that this data is claimed, by a category error, to be a level of representation. Further more, given the preference for phonological data to derive

from broad transcription, this means that surface structure consists mainly of those forms which are easy to transcribe and often which have been conventionally analysed in a previous cycle of theoretical analysis (cf. also Simpson 1999, Port 2007). Stating /t/ allophony in terms of transcribed segments begs the question: it is no wonder so many phenomena can appear segmental and categorical, and hence phonological. Using fine-grained phonetic data might change our conception of the phenomenon, revealing it to be more subtle, variable and less phonological (Docherty 1992; Browman and Goldstein 1989, 1992; Pierrehumbert, 2002), but it might also reinforce its phonological status from a firmer empirical base. Instrumental analysis provides far more information than transcription about the phonetic exponents of phonological systems, but *neither* type of data is a level of representation. From the analytic perspective, phonetic data of any type is a resource which enables a proper consideration of relationships and structures, and is always an abstraction from the real world. Arguments against a naïve phonological interpretation of transcribed phonetic substance can equally be applied to complex phonetic observation. In the end, however much descriptive detail we have, the analyses of phonological allophony and contrast are fundamentally abstract processes. Allophones may be radically different at a phonetic level yet still be argued to belong to the same phonological structure, where general processes of phonetic implementation account for the allophony, or similar phonetically yet differing in phonological specification.

In this paper we will look at one element in Dutch, namely /r/, and how it is realised phonetically, examining how it varies between different places in structure, and in different speakers, appearing as it does with different places and manners of articulation. We follow in the wake of previous work which has uncovered wide variation in Dutch /r/ realisations and considered the implications for phonology (Van der Velde and Van Hout 2001; Plug and Ogden 2002). The detail of such variation lets us consider the tension between an apparently simple phonological abstraction with its theoretical phonological label and feature content (here we use a neutral “/r/” symbol) and the rich and complex phonetic phenomena associated with it.

The question of whether a phoneme has one phonological allophone which varies phonetically in onset vs. coda, or whether it has two (or more) phonological allophonic categories exercises the mind of every phonologist. What is unusual here is that to explore this issue we have undertaken a qualitative instrumental articulatory analysis supplemented with acoustic analysis, to explore the nature of this rhotic consonant from speaker-oriented and listener-oriented points of view. Specially, we have used an ultrasound scanner to capture time-varying images of the tongue (Stone, 1997).

One of the main issues of interest for Dutch /r/ allophony suitable for ultrasound investigation is the relationship between a uvular trill as an onset allophone in combination with a post-alveolar approximant coda allophone, a pattern increasingly found in modern Standard Dutch (Van Bezooijen 2005). The radically different allophones [R] and [ɹ] appear easy to distinguish, and it is a priori tempting to describe /r/ as requiring two different categories which differ in both manner and place. But is this phonologisation? Let us consider more carefully. The basic analytic decision is whether to use feature theory or a language-specific phonetic specification. How are the very different places and manners encoded and distributed phonologically, if indeed they are at all? How powerful is phonetic implementation, if mere phonetics can turn one of these categories into the other?

We were also interested in the analysis of speakers whose coda /r/ sounds rather derhoticised, another pattern found in contemporary Dutch speech (Viergege and

Broeders 1993; Van den Heuvel and Cucchiarini 2001; Plug and Ogden). The development of non-rhotic systems from rhotic ones is very interesting phonologically, and cross-linguistically, because if the /r/ is no longer present as a segmental consonant in the system, but instead has vocalised and been incorporated into the nucleus, then not only have the features for /r/ changed, but the possible syllabic affiliation of those previously consonantal features has changed too. The problem for the phonetics-phonology interface here is no different in kind to the other type, but the answer might appear to be more clearly that a non-rhotic coda is not likely to be a phonetic variant of /r/.

In the rest of this paper we will describe our articulatory and acoustic studies, highlighting the differences between speakers and the allophonic patterns that exist within speakers. We conclude with a discussion about the implications of such data for phonology and try to reject the idea that ignorance is bliss.

2 Method

2.1 Participants

We recruited nine native Dutch speakers staying in Edinburgh, Scotland, with an aim of exploring /r/ systems in which the onset was a uvular trill and the coda a post-alveolar approximant, to see what could be learned about the tongue shape in the coda. All were to some extent bilingual (at least), in the sense that they all spoke English at a high level of proficiency. We cannot be sure how bilingualism (or living in the UK) affected their sound system, and they have varied personal histories, so the sample is not representative of anything more than a random set of younger Dutch overseas students or émigrés. Impressionistically, their Dutch sounded native without traces of second language interference and we have no reason to think that their systems show attrition towards English (de Leeuw 2009), but this has to be acknowledged as a possibility. All speakers spoke Standard Dutch with few traces of regional accents.

It is typical when collecting ultrasound data from subjects that a proportion will not provide usable images, due to a variety of physiological and technical reasons. Four subjects were rejected on these grounds, all of whom had uvular trills in both onset and coda (though one, UB3, had a number of coda post-alveolar approximants). The types of systems that were found from the remaining five female speakers can be grouped into three types, with subject pseudo-initials given accordingly. As will be shown later, these initials are mnemonics for the speakers' articulations. The ordering of the two initials indicates onset, then coda articulations, and U = uvular trill, B = bunched post-alveolar approximant, and R = retroflex alveolar approximant. Numbering is used to distinguish the two speakers who both have a UB system.

- Onset and coda both uvular trill ($n=1$, with 4 rejected) **UU**
- Onset uvular trill, coda post-alveolar approximant ($n=3$) **UB1, UB2, UR**
- Onset and coda both post-alveolar approximants ($n=1$) **RR**
- These five speakers were all from the western or central Netherlands. All three onset/coda patterns are well-known from previous descriptions of Standard Dutch /r/ (Van Reenen 1994, Voortman 1994, Van de Velde 1996).

2.2 Data collection procedure

All subjects were recorded in a sound-treated room at QMU using the equipment and methodology reported by Vazquez Alvarez and Hewlett (2007), which comprises ultrasound scans digitised at 25Hz with an associated acoustic signal synchronised with a temporal alignment error of at worst ± 30 ms. A headset was used to provide stability, holding the ultrasound probe in a fairly fixed location. Clearly, analysis of acoustic/articulatory timing relations is the most problematic analysis type from this body of data, compared to pure formant analysis or pure ultrasound analysis, due to the variable error in alignment. Thus we will approach articulatory and acoustic correspondences cautiously, and qualitatively. The relatively slow-moving gestures required to bring the tongue into target position for both uvular trills and post-alveolar gestures are, however, clearly visible and easy to extract.

The ultrasound probe was held by the headset under the speaker's chin and touching the submental surface, to provide a steady mid-sagittal image, with the tongue blade and tip to the right of the image (Figure 1) and the root to the left (Stone, 1997). The image might not capture the very tip of the tongue due to a non-transfer of the beam through air in a sublingual cavity (caused by tip raising), or by the absorption of the beam by bone in the chin, and, at the root, by absorption by the hyoid bone.

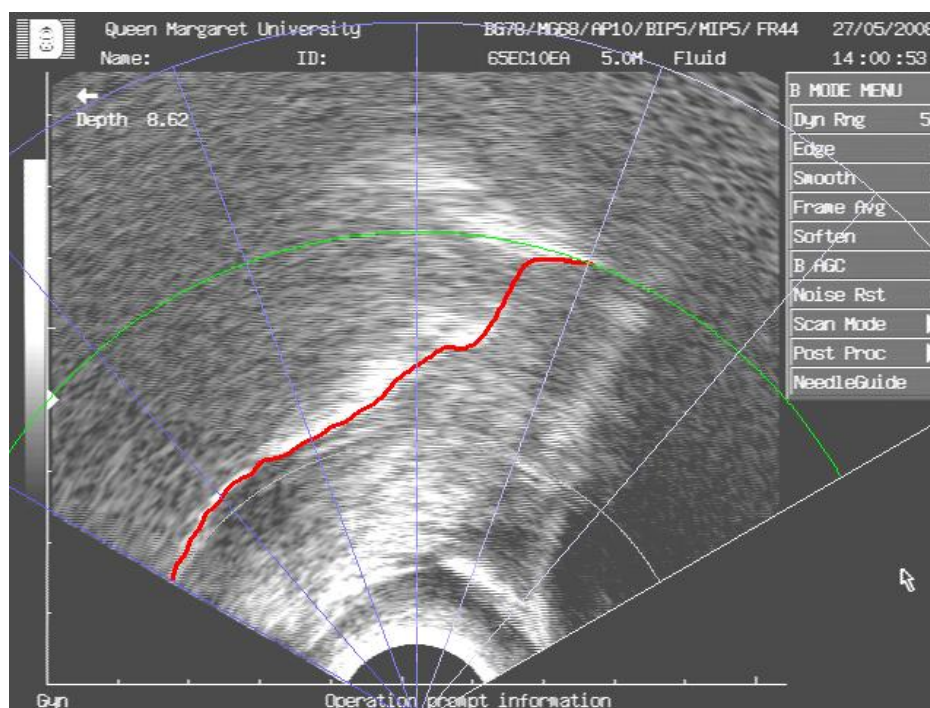


Figure 1 Ultrasound Tongue Imaging, with tip and blade to right, root to left. This is a token of a retroflex or tip up post-alveolar approximant. An analysis curve has been superimposed onto the raw data, at the base of the bright white areas created by reflections from the tongue surface.

It took approximately 10 to 20 minutes to find a combination of parameters and positions to provide the best image quality for each speaker. When the best image was obtained, recording commenced.

As a prompt, speakers were presented with a picture on screen accompanied by a beep and green background, to indicate recording had commenced. The list of

materials was collected in three blocks, each in random order. At least three tokens of each word were collected, and the final three produced were analysed.

2.3 Materials

A short set of materials was used, comprising pictures representing common single-word items in Dutch. To control for C-to-C co-articulation as much as possible, an /r/ was placed as a singleton either in word-initial onset or word-final coda position in a monosyllabic word, with /i/, /u/ or /a/ as the adjacent vowel. The particular focus was /r/ in a pre-pausal coda context, with just one onset type for comparison. The contexts /ir/ and /ri/ are thus the closest onset-coda comparison possible with these materials. In addition, two cluster contexts were examined, /rt/ and /rs/, in which the presence of /r/ created a minimal pair with comparable /t/-final and /s/-final words. These /r/ can be expected to be different from singleton /r/ phonetically, due to coarticulation. There were about a dozen semantic distracters, including some words with /r/ in a different position (e.g. *draad* ‘thread’) which are not analysed here.

Onset:	/ri/	<i>riem</i>	‘belt’
Bare Coda:	/ir/	<i>mier</i>	‘ant’
	/ar/	<i>schaar</i>	‘scissors’
	/ur/	<i>boer</i>	‘farmer’
Coda cluster:	/ɔt/ - /ɔrt/	<i>bot</i> vs. <i>bord</i>	‘bone’ vs. ‘plate’
	/as/ - /ars/	<i>kaas</i> vs. <i>kaars</i>	‘cheese’ vs. ‘candle’

2.4 Measurement

2.4.1 Acoustics

Acoustic measurements were made on the basis of the acoustic data alone, and we undertook two types of acoustic analysis of the four subjects with approximant codas. These measures are indicative and suitable for qualitative analysis, and are not intended for quantitative statistical analysis. First, we measured the duration of quasi-segmental components of the rimes /ir/ /ur/ /ar/. The word was segmented into a steady-state vowel portion (if any), a transitional formant movement, and finally any steady-state rhotic (if any). We noticed that there was frequently a voiceless offglide from the end of the word, a transition into post-speech silence which could have a rhotic quality, so this was also annotated if present. It was a weak fricative which could be uvular, post-alveolar, or like a voiceless vowel in character. Duration measures are presented not normalised in order to present more direct and qualitative characterisation of timing and duration. No durational analyses of the minimal pairs were undertaken.

Second, we made manual formant measurements of F1, F2, and F3 (in the AAA software) at a single point in each of the three voiced events, to see how closely approximated F2 and F3 are, which is a typical correlate of a post-alveolar rhotic (e.g. Guenther et al., 1999). For /ur/, /ir/ and /ar/, the measure was taken at the time when the formants were most closely approximated, which was late in the rime. For the minimal pairs *bot* vs. *bord* and *kaas* vs. *kaars*, a point approximately midway in each of the three events (vowel, transition and rhotic) was chosen. If there was no steady

state rhotic, then the end of the voiced transition portion was chosen because it would be the most rhoticised part of the voiced part of the rime, immediately before the final consonant. The final consonant could well be coarticulated and thus reflect the presence of /r/, but we have not measured it here (though such variation would illustrate our theoretical questions about what level of phonetic detail is encoded in surface structure.)

Together these findings let us compare across speakers in broad terms, support the impressionistic analysis, and reveal in a quantitative analysis the extent to which the formant values and the duration of the final phase reflect the impressionistic rhoticity of the speakers.

2.4.2 *Articulation*

As mentioned above, a line is fitted by hand using AAA software onto any ultrasound frame which is to be used for further analysis. In this dataset, using the technology available at the time of data capture (cf. Vasquez Alvarez and Hewlett, 2007) frames are about 30ms apart and are not consistently well-aligned to the acoustics. In order to extract a single frame as the basis for an analysis of the /r/, two methods are available. One is to analyse a frame based on it being closest in time to some acoustic landmark, such as the end of voicing or F3 minimum, which is thought to be the acoustic temporal location of the /r/. The second is to choose a frame which has the clearest articulatory characteristics of an /r/, whether it be a post-alveolar or uvular constriction. Both methods mean we have to tolerate some articulatory-acoustic indeterminacy, and we feel that in an articulatory analysis, an articulatory definition of the annotation point makes more sense. In addition, F3 does not always lower. Thus the approach we present here is based on frames which were judged to be the single frame in the word in which the tongue shape was the most extreme, clearest articulation of /r/. By and large, this frame was at the end of phonation in the transition to silence. Thus, in this dataset, that particular acoustic landmark could have been chosen, and it gives very similar results.

The curve drawn onto the raw ultrasound image (Figure 1) was exported in Cartesian coordinates to a spreadsheet, using AAA software (Articulate Instruments, 2008), as the basis of an impressionistic analysis. Quantitative analysis was not felt to be appropriate, given the small numbers of tokens per speaker per condition, but the curves can be overlaid and compared. Tongue shapes can be qualitatively assigned, based on the types of /r/ constriction proposed by Delattre and Freeman (1968).

3 Results

3.1 *Impressionistic results*

Speaker RR sounds highly derhoticised in the coda, especially after /a/ (which is a familiar pattern from Plug & Ogden 2002), with residual weak anterior rhoticity of some kind in some tokens. Unlike the other speakers, she clearly has a post-alveolar approximant in the onset rather than a uvular trill. Other speakers sound more rhotic in codas but vary greatly in the apparent dynamics and vowel duration. Speakers UR, UB1 and UB2 sound particularly rhotic. Finally, UU has uvular trills mostly, but a few tokens sound more like voiced fricatives, which is expected from descriptions of Dutch (Collins and Mees 1996: 200) as well as cross-linguistically (Lindau 1985). We

are not confident that we can correctly label the approximants as being bunched or retroflex on an impressionistic basis.

3.2 Acoustic results

We will present the durational characteristics of the speakers first, then the formant measurement results.

3.2.1 Durational analysis

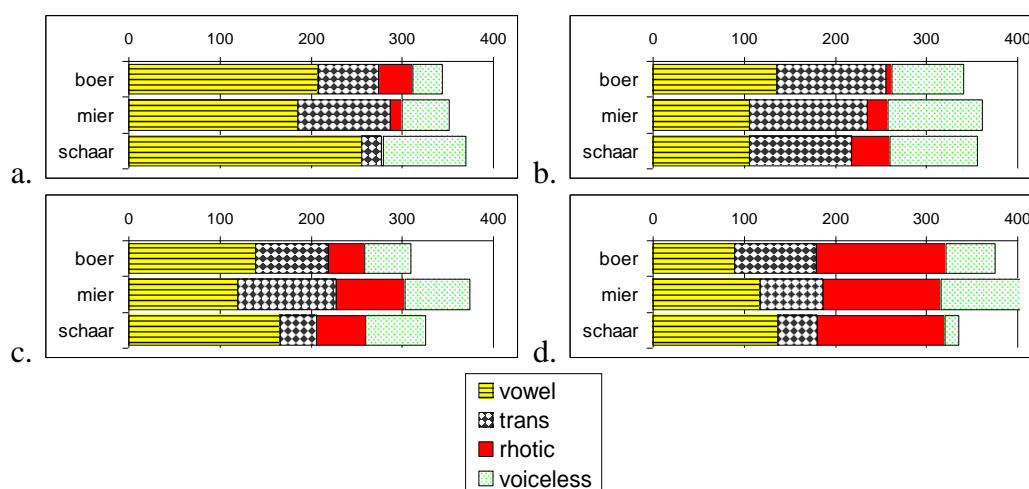


Figure 2 Durations (ms) of acoustic events in syllable rime of /r/-final words; speakers a. RR b. UR c. UB1 d. UB2

Figure 2 reflects our impression that speaker RR differs from the other subjects in being derhoticised, because she has long steady-state vowels, with an audible offglide but without the period of qualitatively stable phonetic rhoticity that the other subjects have. UR, on the other hand, sounds appreciably rhotic, even though her steady state rhoticity is also short, and the V-/r/ transition is long, showing that the auditory percept of rhoticity is not necessarily conveyed by a stable rhotic post-alveolar approximant, and that quality (unsurprisingly) is also important. But, the differences between the speakers in their rhotic portion is remarkable. UB2 has very long steady-state rhoticity and much shorter vowels. Overall, all speakers have comparable rime durations, at around 250 ms to 300 ms, with on average a bit more than 50ms of weak voiceless friction, typically from a glottal source, which can have a faint rhotic quality.

3.2.2 Spectral analysis

First, we present the results for the simple rimes. Figure 3 shows that three speakers approximate F2 and F3 much more closely than the fourth, RR, reflecting the impressionistic derhoticisation of this speaker. Recall from Figure 2 that RR has long steady state vowel with short offglide transitions and little rhotic steady state, if any (so that /ar/ was nearly monophthongal), while UR had long transitions towards a relatively short rhotic steady state, which perhaps accounts for her F2-F3 approximation appearing to be slightly less tight than UB1 or UB2.

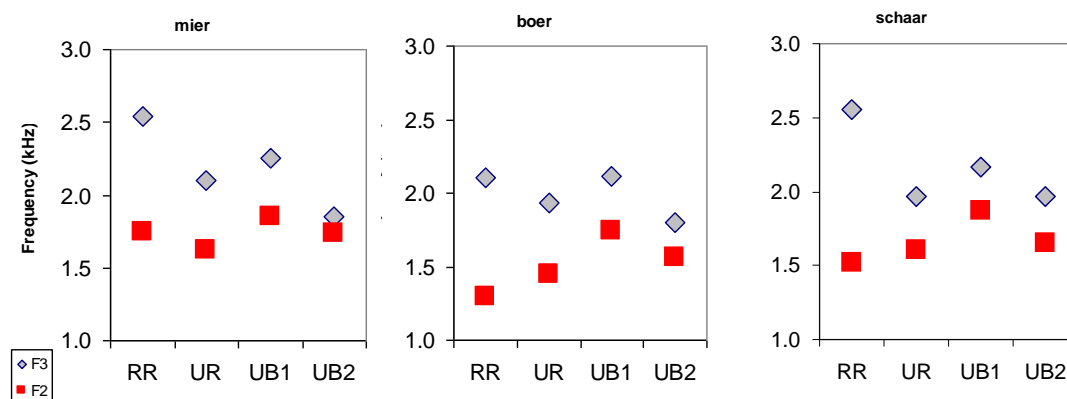


Figure 3 Second and third formants during their closest approximation in a rime ending with phonological /r/.

Across speakers, there is some consistent coarticulation with the preceding vowel, such that F2 and F3 are both lowered following /u/. The consistently higher formant values for UB1 likely reflect a smaller vocal tract size Table 1 shows the mean F3-F2 value calculated from the nine pooled tokens per speaker.

Table 1 Mean F3-F2 in the approximant singleton coda /r/

	RR	UR	UB1	UB2
mean	884	443	222	359
s.d.	180	70	110	81

We turn now to the minimal pairs. In Figure 4 and particularly in Figure 5 RR (a) again has far weaker acoustic contrast in terms of the formant frequency in F2 and F3, especially for the low vowel context (about an 800Hz difference in *kaars* vs. about 1200Hz in *kaas*). The other speakers' rhotic formant values (with the crosses) show clear approximation of F2 and F3 in the rhotic phase (R) (about 200Hz vs. about 1200Hz). In addition to these spectral differences, the rhotic rimes tend to be longer in duration and there are some coarticulatory effects attributable to /r/ in the final stop and fricative. But even in these tokens, as in those shown in **Figure 2**, RR has a long vowel with shorter transition and an almost absent rhotic steady state. On the other hand, the F1 values show that there is no transfer of contrast to a vowel quality difference. We are not claiming that there is neutralisation here in RR's speech, but rather we have shown that the impression of derhoticisation in RR's speech (stronger in some tokens than others) is supported by acoustic analysis. Even within the category of "post-alveolar approximant" for coda /r/ may be a wide range of variation in the acoustics, from a strong to an almost absent rhotic quality on average, with individual tokens completely lacking any impressionistic quality of rhoticity at all in the case of the rime /ar/.

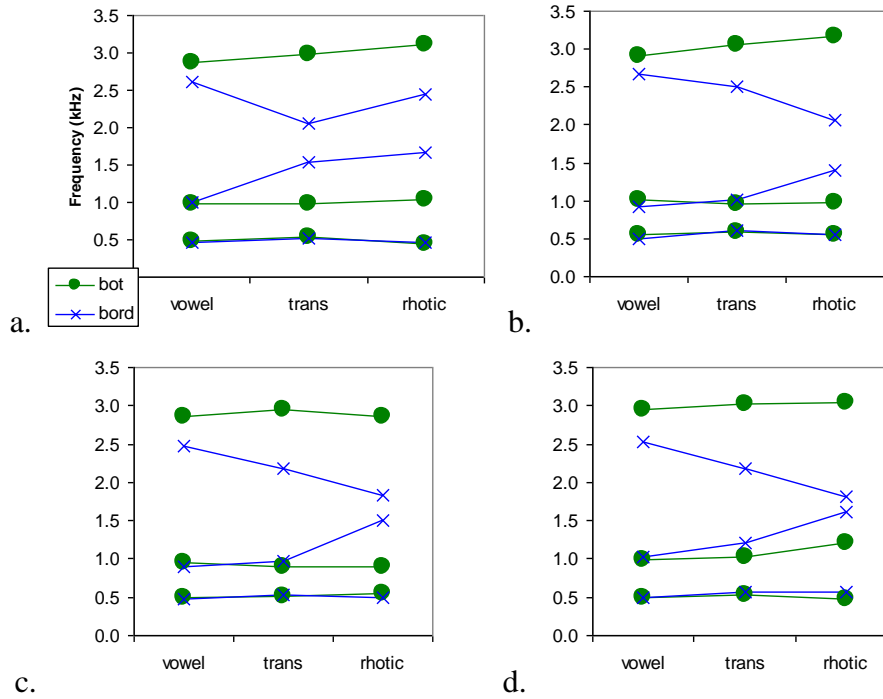


Figure 4 The first three formants in a rhotic (crosses; bord) vs. rhotic-less (circles; bot) stop-final minimal pair, normalised time; Speakers a. RR b. UR c. UB1 d. UB2.

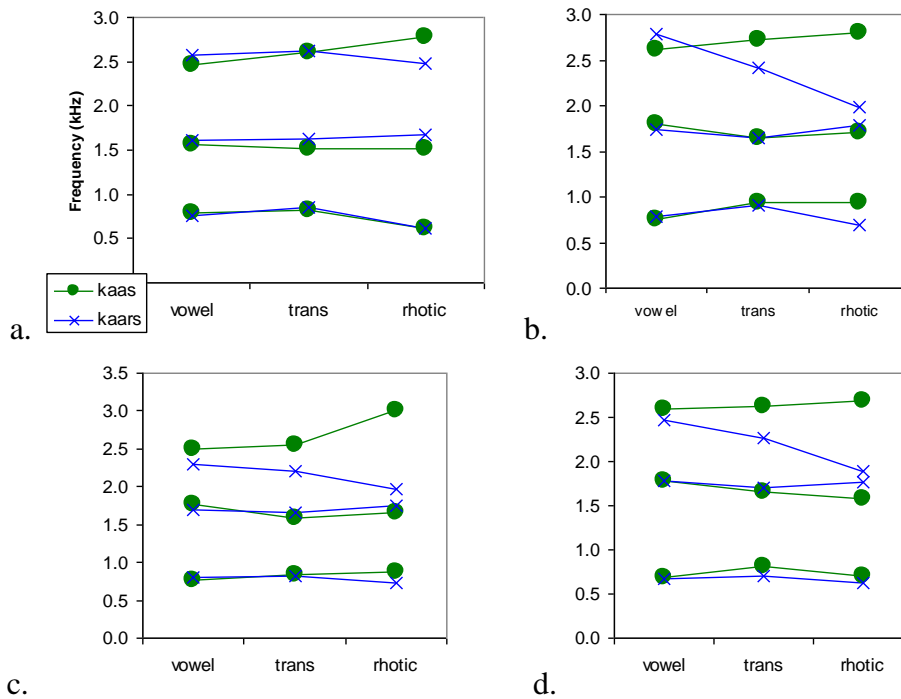


Figure 5 The first three formants in a rhotic (crosses; kaars) vs. rhotic-less (circles; kaas) fricative-final minimal pair, normalised time; Speakers a. RR b. UR c. UB1 d. UB2.

3.3 Articulatory analysis

The acoustic discussion concentrated on some important spectral and durational characteristics of the vocoid rime corresponding to the coda approximant /r/. In the articulatory analysis we look at singleton /r/, contrasting the tongue shapes of onsets and codas within speaker, and examining interspeaker differences.

Recall that three speakers appear to have a strong categorical distinction between onset and coda allophones, given that onsets are uvular trills and codas are post-alveolar approximants. In Figure 6 (Speaker UR) and Figure 7 (Speakers UB1 and UB2) are the three tokens each from onset /r/, from /ri/, with three tokens from coda /ir/, overlaid in articulatory space. (Not shown is the tongue shape for /i/, which is, in both *mier* and *riem*, a palatal constriction with advanced tongue root very different from the shapes for /r/.)

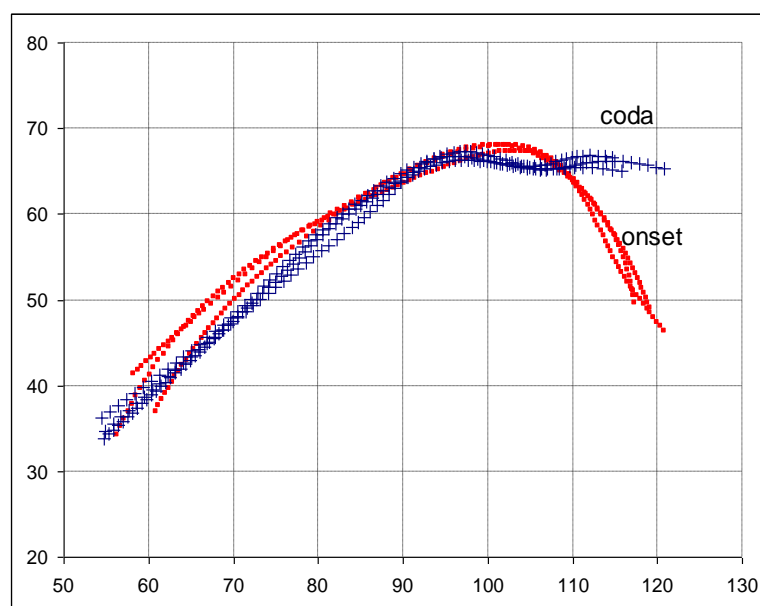


Figure 6 Extracted tongue surface contours from the three tokens of speaker UR's onset /r/ (crosses) and coda /ir/ (small squares), showing broadly comparable pharyngeal contours (on the left of the image) but with clear anterior tip raising (on the right) in the coda but not in the onset. Horizontal and vertical measures are in mm from an arbitrary origin. Subsequent figures follow these same conventions.

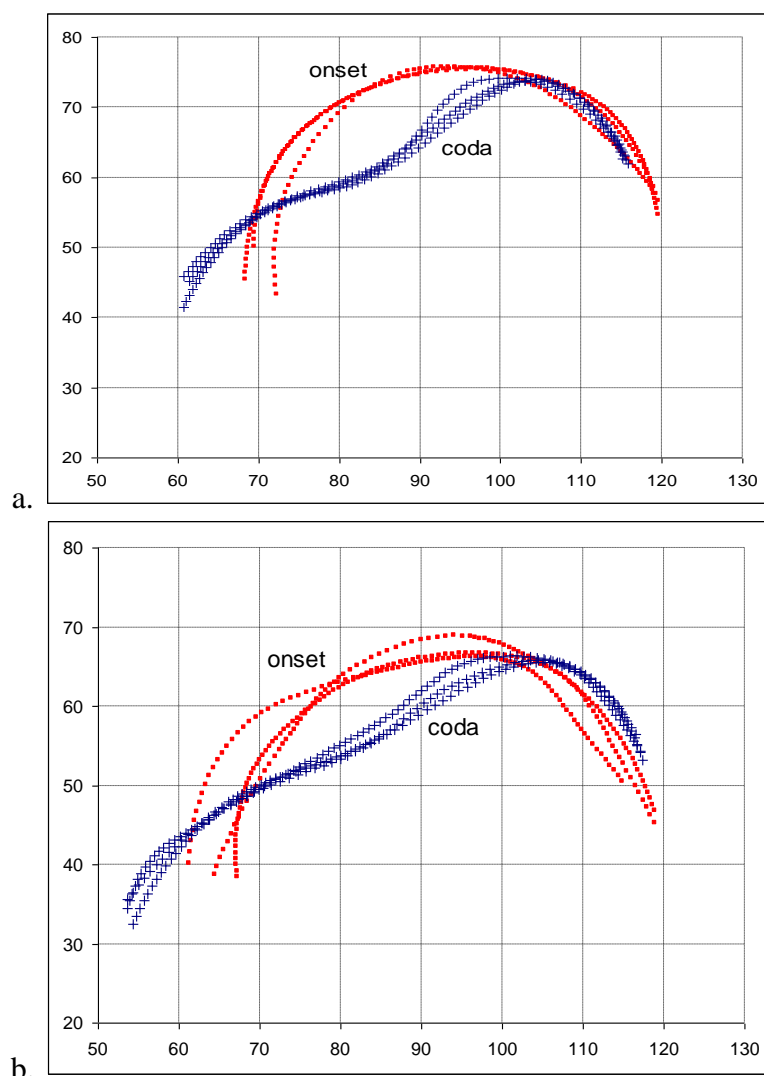


Figure 7 Extracted tongue surface contours from a. UB1 and b. UB2. Both show a near semi-circular shape for the uvular trill in onset /r/ vs. a clear double articulation for the post-alveolar approximant coda /r/. The latter has a retracted tongue root, a tip-down post-alveolar constriction, and a saddle in between.

Both speaker UB1 in Figure 7a and UB2 in Figure 7b show a large onset-coda allophonic difference. They have a post-alveolar approximant coda /r/ which is bunched (tip down), unlike UR (Figure 6) or RR (**Error! Reference source not found.** below) who have a tip-up or retroflex articulation (finally providing the evidence for the five speakers' code names as mentioned in the Method section). Note, however, that in Figure 7a in Speaker UB1, the anterior part of the tongue in the onset uvular trill appears to be approximated to the post-alveolar region as a secondary articulation, just as closely as it is for the coda, where this is said to be the primary articulation, a pattern which UB2 may have too, though it is less clear.

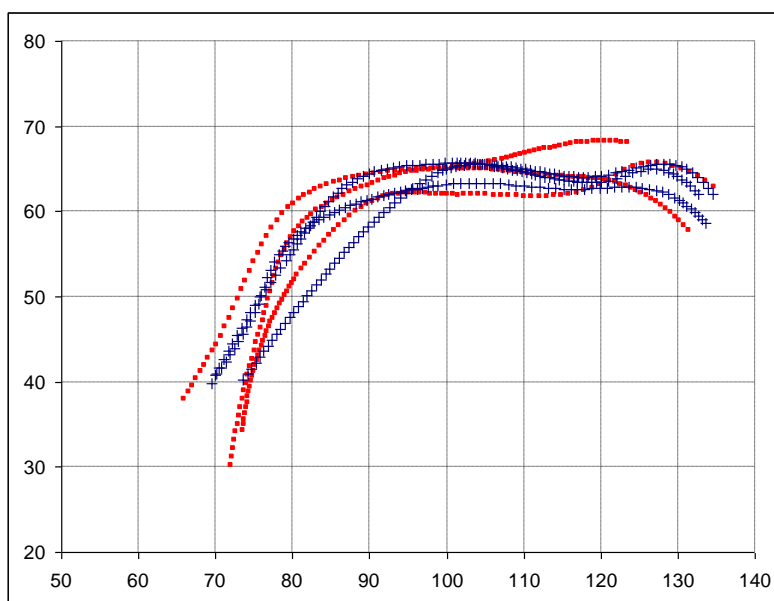


Figure 8 Extracted tongue surface contours from the three tokens of speaker RR’s onset /ri/ (crosses) and coda /ir/ (small squares), showing comparable retroflexion in both, with greater token-to-token variation than other speakers.

For speaker RR, who has an approximant onset, Figure 8 shows that articulatory rhoticity in the coda is clear and comparable in strength to the onset, despite both impressionistic and acoustic coda derhoticisation. Although the acoustic point at which this occurs cannot be identified with high temporal accuracy, it appears that this constriction target occurs roughly at the termination of phonation or even *after* its offset, which would explain why the degree of raising that is present does not appear to generate as such strong an impression of rhoticity as it does in the onset. Of particular interest is the clearly visible but acoustically covert tip raising in *schaar* (Figure 9 **Error! Reference source not found.**), the rime of which is nearly monophthongal (Figure 3).

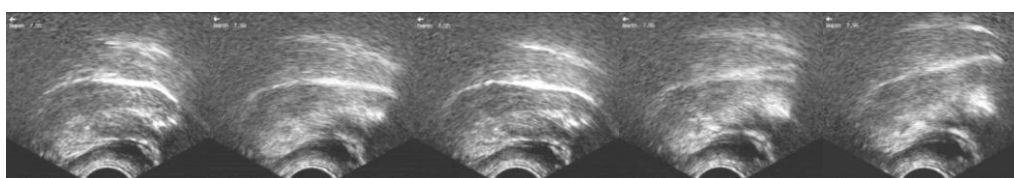


Figure 9 Time series of ultrasound images (speaker RR, *schaar*), showing tongue raising in the four frames (120ms) leading to a tip-up constriction in the fifth. Offset of voicing occurs roughly around frame 4.

Examination of static and dynamic ultrasound data and further tongue curves for this speaker show that RR has a post-alveolar tip up approximant articulation after all three vowels /i/, /u/ and /a/, where it is very clear that the tongue tip is raising away from the configuration required for the preceding vowel nucleus. The label “covert” for this articulation is most appropriate in the context of /a/, since /i/ and /u/ have centring and slightly rhoticised offglides, but RR generally has a disparity between the more strongly rhotic articulation and the more weakly rhotic acoustics in all rimes. In addition to the articulatory comparisons between onset and coda /r/ in the /i/ context, we looked at the /r/-ful words (*mier*, *boer*, *schaar*) vs. /r/-less rimes (*riem*,

koe and *sla*). All the articulatory evidence points to there being rhotic post-alveolar and pharyngeal approximant targets conditioned by /r/ in onset and coda alike, whereas the acoustic evidence points to a lack of acoustic rhoticity in the coda.

RR does, however, appear to show more coarticulation between her /r/ and the preceding vowel than any of the other speakers, and more token-to-token variability, suggesting the gestural target location is more likely to be undershot and coarticulated than other speakers. Though onset and coda /r/ appear comparable in constriction strength and place, perhaps better data would reveal that gradient contextual weakening of the critical articulatory gesture contributes to the acoustic derhoticisation, but it seems clear at least that the late timing of the tip raising to a post-alveolar or alveolar location gives rise to a. long vowels, b. late transitions and c. weak acoustic rhoticity.

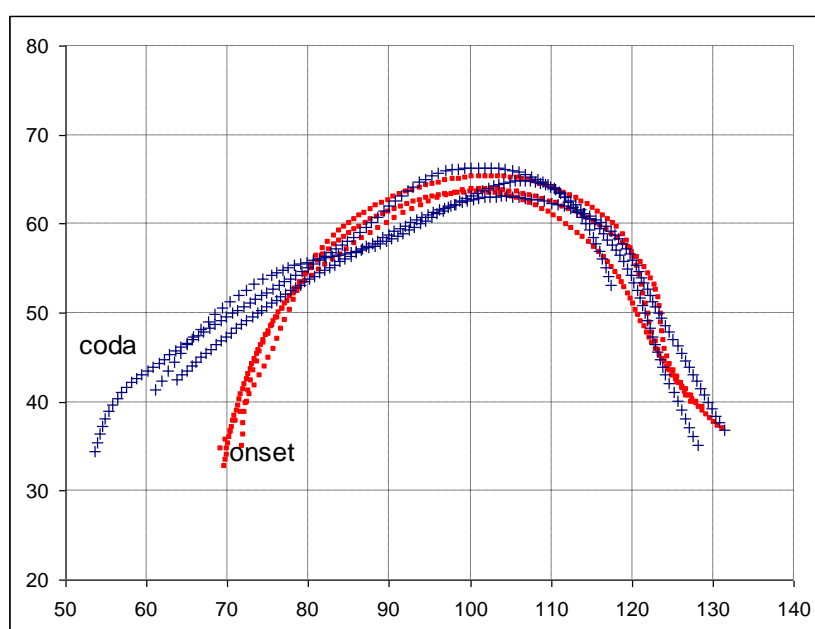


Figure 10 Coda uvular trill /r/ from UU with a pharyngeal retraction not present in the onset

Finally, consider speaker UU (Figure 10), who has uvular trills in the coda as well as the onset. Like speakers UB1 and UB2, her coda has an extra, strong, pharyngeal constriction. Thus overall, all speakers have a pharyngeal constriction for coda /r/. Examination of dynamic changes in articulation show that UU's tongue root is advanced for /i/ and /u/ vowels in *mier* and *boer* and then clearly retracts for /r/. She has a pharyngeal constriction already during the /a/ vowel in *schaar*. The same is true for UB1. UB2 shows much more coarticulation throughout the vowel before the /r/, so that /i/, /u/ and /a/ before /r/ all have a more similar constriction to each other, as well as similar to /r/, than /i/, /u/ and /a/ from /r/-less rimes (*koe*, *sla* and *riem*).

Finally, let us take a cross-speaker perspective, though this is difficult because the speakers all have different-sized vocal tracts, and the rotation and location of the probe is to some extent uncontrolled. However, the clear division into tip-up (UR, RR) and bunched (UB1, UB2) approximants can be emphasised by overlaying all the speakers. Taking a token from *boer*, we extracted a curve for /u/ and another for /r/. We rotated and translated each speaker's pair of curves (i.e. without transforming the size or shape of the curves at all) so the /u/ curves were aligned as far as possible, and

then examining the shape of the /r/ curve (Figure 11 **Error! Reference source not found.**). The results show four comparable shapes for /u/ but two quite distinct /r/ patterns. The bunched /r/ might be more retracted, but it's not clear that this is a genuine pattern without more information about the passive articulator.

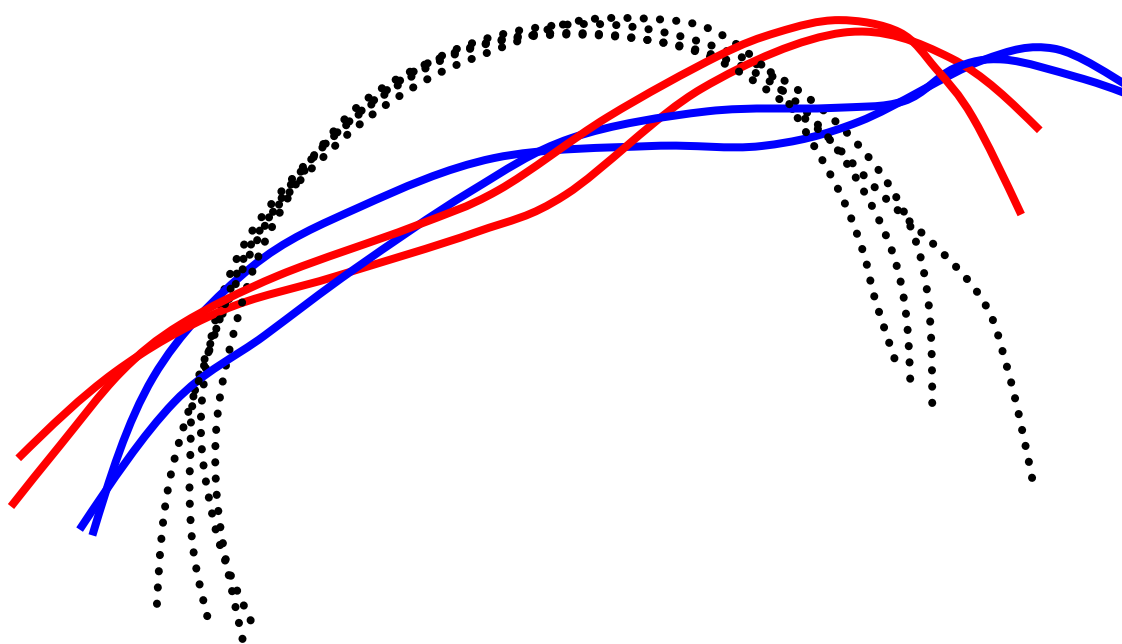


Figure 11 Overlaid tongue curves from “boer”, showing consistency in /u/ (dotted lines) and variation in /r/ (solid lines) with two bunched tip-down (UB1, UB2) and two tip-up slightly retroflex (RR, UR) post-alveolar approximants.

4 Discussion and phonological interpretation

Our study adds further phonetic detail to previous work which shows that different speakers of Dutch have different systems of onset-coda allophony for phoneme /r/. Since allophony can include both abstract categorical relationships *and* subtle phonetic contextual variation, the Dutch situation is just one instance of a common interface problem for phonetics and phonology: it is necessary for Generative Phonology to say which allophonic relationships are abstract and phonological, requiring different specifications of place and manner in surface structure, and which are phonetic, where a single segmental specification is realised differently by phonetic implementation on the basis of the difference in prosodic structure. The phonetic data presented here are tantalising, rather than conclusive, and serve both to remind us how inadequate a source of data a broad impressionistic transcription is, how indeterminate and complex a small sample of phonetic data can be, and, most importantly, that it is necessary to provide direct evidence of claimed articulatory factors. Phonological theory relies rather heavily on articulatory labels for its categories, both in terms of manner and place, so there is a clear advantage for the theorist in seeing some of the articulatory details of the phenomena they discuss.

Our acoustic and impressionistic data superficially support previous impressions that Dutch /r/ allophony is abstract, categorical and phonological, with

different place and manner features required for onset and coda allophones. There are, in addition, some differences in the timing of the vowel-approximant rime, where these appear subtle and are probably specified phonetically through differences in gestural strength and timing. Most significant in that regard is speaker RR, whose approximant /r/ in the coda can be heavily derhoticised (cf. similar cases in Plug and Ogden 2003), apparently even deleting /r/ in some tokens. Her “deletions” are probably gestural coda weakening (in the sense of Browman and Goldstein 1992). However, the articulatory data reveals that every case is more complex and subtle, and that the drawing of the interface as stated above would be inadequate.

First, consider the simplest case, speaker UU, who lacks overt allophony because she has a uvular trill for /r/ in both onset and coda (Figure 10). Ultrasound reveals that she has an extra secondary pharyngeal constriction in the coda. Whether this specification is gestural or feature-based, such a pattern, if general, would be a challenge for most theoretical approaches (e.g. the otherwise very different Goldsmith 1990 and Browman and Goldstein 1992), which argue for the coda being a location for phonological and phonetic weakening, rather than augmentation by a gesture or feature.

Speakers UB1, UB2, RR and UR have a post-alveolar approximant coda, but in two cases it is bunched (UB1, UB2), and in two, retroflex (RR, UR). Is this configuration of the active articulator encoded in phonological structure? If not, this is presumably because the distinction is assumed to have no phonological relevance beyond cueing the phonotactic context (Mielke et al in press), but this is something that must be investigated further. All four approximants have some degree of pharyngealisation, but the bunched approximants might be phonetically more retracted, which is another avenue for future work. Finally, the fact that approximant /r/s are doubly articulated (in the coda and, in the case of RR, in the onset) means that the traditional label of “post-alveolar” is oversimplistic.

The speakers with trill / approximant allophony appear to be superficially the most abstract and phonological, changing manner and place, but the articulatory data suggest a phonetic gestural approach may be more appropriate than it seems at first. First, consider our new finding that speakers UB1 and UB2 have an additional pharyngeal constriction in the coda, like UU. This suggests they have a general coda pharyngealisation, since it appears in variants of /r/ which impressionistically have quite different places and manners. The second new finding which we have made relates to the onsets of UB1 (and of UB2 to a lesser extent). These speakers’ uvular trills involve a post-alveolar secondary articulation.

There may be functional reasons for both these secondary articulations. If a uvular trilled /r/ contains a post-alveolar constriction, rhotic correlates due to F3/F2 approximation will still occur even if there is no trill. It appears from a major cross-linguistic survey (Jones 2009) that lack of actual trilling (what Jones called “trill failure”) is typical of trilled /r/, due to undershoot, increased lingual tension or other causes. It seems reasonable that since weakening processes particularly affect codas, an approximant production instead of a uvular trill may become the established target for coda /r/. What would appear arbitrary – that the approximant resulting from uvular undershoot is post-alveolar – appears to be less surprising now that we have seen the UTI data showing double articulation.

Moreover, it appears that perhaps we can understand that there may be articulatory commonalities behind the impressionistic variety that exists in Lindau (1985)’s family of rhotics, though we still need to explain the ultimate origin of these secondary articulations. We cannot tell whether a post-alveolar constriction is present

for perceptual reasons (to ensure alternative rhotic cues are present for the listener's benefit on cue failure), or as an articulatory side-effect (generating a rhotic approximant by accident, as it were), or both. Does it even matter, perceptually?

All we can do here is note that it appears that a combination of phonetic factors such as trill failure, the presence of an appropriate secondary articulation, and a tendency for phonetic coda weakening together could be the origin of the apparently abstract onset/coda allophonic pattern of uvular trill vs, post-alveolar approximant. Distinct phonological representations would not be needed as part of an *explanation* of the origin of the allophony, though they could be a diachronically later development. The post-alveolar constriction could be covertly present in onset and coda in speakers with uvular trills (though whether this is in some or all remains to be seen), "waiting for its chance to emerge" on trill failure. We could thus conclude that a phonetic account of the origin of the allophony seems more likely.

Turning now to the pharyngeal articulation which appears to be added in the coda, this is not predicted by either a phonological or a phonetic account of coda weakening. Thus we need to take into account both individual systems and the existence of variation in the community. Perhaps speakers like UB1 and UB2 are at a more advanced stage than UU of re-phonologisation. They may be part of a group of uvular-trill-in-onset speakers for whom the pharyngeal constriction in the coda has enabled the loss of trilling in the coda and the establishment of a more abstract allophonic relationship between the forms of /r/, as suggested above. Perhaps, however, the causality runs the other way, and a pharyngeal constriction is present for speakers like UU during their coda uvular trills precisely because some Dutch speakers have approximant coda /r/ already.

The strongly rhotic post-alveolar approximant found here with speakers UB1 and UB2 is also found with speakers of Standard Dutch who have apical alveolar trill or tap onset allophones (Sebregts et al. 2003). For a postalveolar approximant to arise diachronically from a more constricted apical alveolar /r/ is considerably less surprising phonetically than the possible link between such an approximant and uvular /r/. Given the sociolinguistic status of the postalveolar coda approximant in the Netherlands (a rapidly spreading prestige variant, associated with younger speakers, middle-class and female), the wholesale borrowing of this variant by speakers that do not have an articulatorily relatable onset /r/ cannot be excluded as a possibility. It is of course impossible to tell if borrowing has indeed taken place for the speakers in our sample, or whether they have simply acquired this now well-established allophony due to it being present in their ambient environment. In any case, the presence of a postalveolar constriction during the articulation of the uvular trill for speaker UB1, as well as the presence of a pharyngeal constriction throughout the articulation of both the uvular and postalveolar allophones for UB1 and UB2 suggests that these speakers have some sort of concrete and systematic link between their onset and coda allophones that is not obvious from impressionistic analysis.

Finally, let us consider the derhoticisation of RR. It appears impressionistically that RR deletes /r/ in some tokens, and weakens it in others, and on average, she generates very small F3/F2 cues to rhoticity. In fact, the articulatory evidence reveals that in pre-pausal position, she has a strong and consistent post-alveolar retroflex articulation, one which seems to generate very little overt acoustic rhoticity. Our view is that this covert rhoticity highlights the complex relationship between articulation and acoustics even more keenly than the secondary articulations that accompany the very salient acoustic effects of trilling discussed above. Speaker RR is derhoticising in the coda from the point of view of other listeners, and articulatorily, this weakness is,

before silence, achieved through some kind of gestural delay rather than phonetic gestural weakening, let alone categorical phonological deletion. Our hypothesis is that the anterior constriction for /r/ is made, but close to and often after the offset of phonation. At most, RR generates a very weak voiceless excitation of a rhotic constriction. In pairs like *kaas* vs. *kaars*, the contrast seems very weak indeed, and perceptual analysis of the output of such speakers is clearly a priority for future research. Our acoustic and articulatory data appear to support the observation by Plug and Ogden (2003) that a variety of phonetic correlates other than formants cue the presence of /r/, such as, in -/rs/ and -/rt/ clusters, the place of articulation of the following obstruent.

In connected speech and word-internally, yet further variation is, we think, highly likely. From this dataset we know that RR's anterior constriction appears to be very weak or absent as an independent consonant when /r/ is immediately followed by an anterior lingual consonant within the same word. There is coarticulation, so that the following consonant is a slightly rhoticised variant itself (where we see no motivation to represent this minor difference phonologically). Phonetically, it appears that the weakening and delay of the anterior /r/ constriction means that it is largely masked acoustically (in terms of F3/F2) though the post-alveolar gesture is incorporated through coarticulation into the following consonant.

As for word-final /r/ phrase medially, a small follow-up study with RR reveals strong variation, which if recorded in broad transcription would likely be treated as a categorical external sandhi (Van den Heuvel and Cucchiari 2001).¹ Word-final /r/ before some consonants (*ik zie vier mieren* and *een paar vazen*) has scarcely any post-alveolar gesture – it is reduced rather than delayed and is barely still visible articulatorily. However, RR's word-final /r/ is realised as a post-alveolar tap or an impressionistically strongly rhotic approximant before a following word-initial vowel (e.g. in *een paar azen*, *ga er maar aanstaan*, and *de boer oefent*). The preceding vowel sounds long and monophthongal. Rhoticity is present even if word-boundary glottalisation intervenes, arguing against phonological resyllabification (Scobbie and Pouplier, under review). If the following word begins with a voiceless /p/ (*de boer poetst*), the acoustic and impressionistic story is still that RR is derhoticised. However, unlike the cases above of gestural reuction, articulatorily, there is a strong rhotic gesture, masked by the silence of /p/. Before moving on, we should note that the sort of gestural delay shown by RR might even give some insight into the diachronic origin of floating phonological features and external sandhi “resyllabification”.

Our hypothesis (which cannot be tested without further data) is that the variation presented here in the coda forms of RR is gradient in character, suggesting that the choice between spatial undershoot vs. temporal delay implementations of weakening may be structurally conditioned by prosodic categories but not be categorical or deterministic, making them less likely to be encoded categorically in phonology as alternatives. Additionally, we think that the acoustic consequences of the undershoot (e.g. derhoticisation) count as a target and therefore as a representation of phonological structure as least as much as the articulation does. So, the phonological representation of /r/ ought to be abstract, and not too wedded to phonetic substance, since the substance has articulatory and acoustic characteristics trading off each other in a complex pattern which reflects phonological and prosodic context, patterns which

¹ In this work, an automatic speech recognition device decides on the presence of /r/, where only categorical absence or presence is allowed. In other works, such as Vieregge & Broeders (1993) and Van de Velde (1996), some /r/ are transcribed as “zero” on the basis of purely acoustic data.

may have to be understood via far more phonetically-detailed models than those offered in traditional phonological formalisms, more along the lines of Browman and Goldstein (1992), Docherty (1992). Boersma (1989), Pierrehumbert (2002) or others.

It should be clear that neither the acoustic nor the articulatory patterns found need to be the *automatic* consequence of some strategy. Functional explanations, such as preservation of contrast, or ease of articulation, are not deterministic, though they surely have a role to play. This lack of determinism means that formal models of such patterns are descriptive but not explanatory (Scobbie and Stuart-Smith, 2008). It is not to be denied that formal descriptions are preferable to informal ones, but explanation is too strong a claim.

Cross-linguistic support for the interpretation of derhoticisation presented here came from covert rhotic-like lingual articulations which were observed in a single case study of a derhoticing Scottish speaker (Scobbie, and Stuart-Smith, 2005), very similar to RR. Since derhoticisation in Scottish English is very well-established (Romaine, 1979, Stuart-Smith, 2007), but its phonological status remains unclear, the possibility that these patterns of articulation are part of an early stage in sound-change towards non-rhoticity appears more feasible than the Dutch data alone would suggest. The more general existence of covert rhotic articulations among vernacular Scottish English speakers has been further evidenced in recent work (Lawson, Stuart-Smith and Scobbie, 2008, Scobbie, Stuart-Smith and Lawson, 2008).

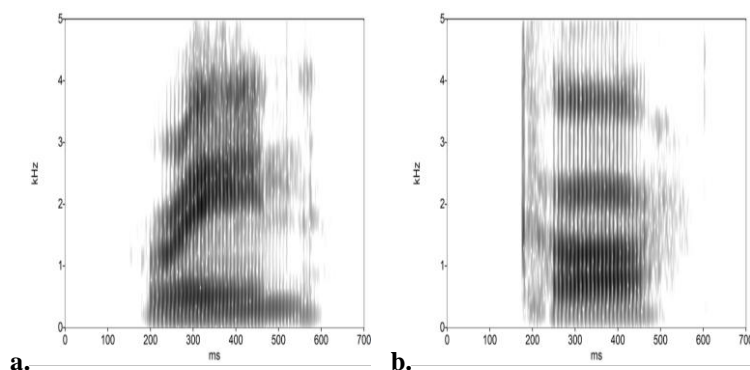


Figure 12: Examples of onset rhoticity in (a) *rain* vs. coda derhoticisation in (b) *car*, from a Scottish speaker P0.

In Figure 12 we illustrate the acoustic output of the Scottish speaker P0. His /r/ can be seen to be a strongly rhotic approximant in onsets (Figure 12a), but in codas, it is either a derhoticised pharyngeal or centering offglide (entirely typical of derhoticising Scots) and in low back vowel codas, the rime has a monophthongal quality (Figure 12b). This prepausal token of /kar/ has widely-spaced F2 & F3 with a merest hint of F3 lowering and F2 raising in the devoiced phase.

Ultrasound Tongue Imaging reveals a similar complex situation to Speaker RR above, with P0's tongue shapes in a pre-pausal coda being very similar to those observed in canonical rhotics. Figure 13a shows the position of the tongue approximately at the end of phonation of the token of *car* in Figure 12b. In the silence after the citation form is complete, a tongue-blade raising gesture occurs (unlike RR, this is a bunched articulation), roughly towards the post-alveolar region (Figure 13b).

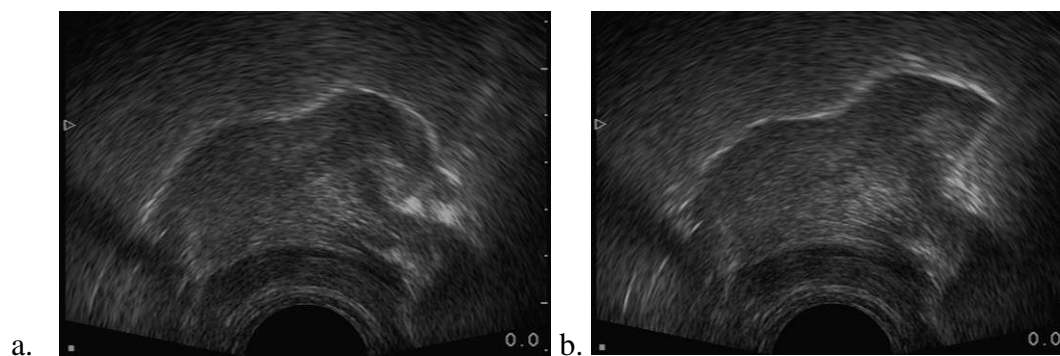


Figure 13. Ultrasound frame (a) from the end of phonation of P0's *car*, and (b) three ultrasound frames later (120ms), by which time the attainment of maximal tongue blade raising has been achieved.

To conclude, we return to the point that “the” phonetics-phonology interface is multifaceted. The superficially mismatching patterns of articulation and acoustics presented here suggest a complex interplay between these observable and measurable phenomena and the abstract systems which underlie them, whether those systems be formalized in theoretical frameworks which stress categorical algebraic relationships (typically phonology) or are heavily quantificational (typically phonetic). Detailed phonetic data (from articulatory, acoustic or perceptual research) suggest different and more complex conceptual relationships between phonetics and phonology than are normally entertained when the only source of information about phonetics comes from pre-categorised, segmental transcriptions. These more complex relationships may well be better able to answer some questions, or point in the right direction, at least. Is there some discrete difference between phonological systems which have a coda /r/ and those which do not, and if so, how do these changes occur? Are uvular trill and coronal approximant allophones of /r/ discretely different, and if so, how do they emerge as allophones of the same phoneme? We have to conclude that such fundamentally phonological questions can only be addressed through large scale studies which provide detailed data about speech production as part of a renewed commitment to the empirical underpinnings of our field.

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