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Acoustic, Articulatory, and Phonological Perspectives on Allophonic Variation of /r/ in Dutch*

JAMES M. SCOBBIE AND KOEN SEBREGTS

15.1 Introduction

One of many difficult areas for the phonology-phonetics interface 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 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. '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 non-phonological 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 [th] in the onset and [ʔ] in the coda and [t] in initial /s/ clusters, etc. It is important to note that the prosodic structures and linear order of segments in the surface level of representation already provide 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

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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 Pierrehumbert, Beckman, and Ladd (2000), Cohn (2006), and 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 fineness of phonetic transcription constitutes the raw data for phonological analysis. It seems sometimes that transcription data is claimed, by a category error, to **be** a level of representation. Furthermore, 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 and Leary 2005). 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, if the data is prepared at the appropriate level of granularity. 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 raw 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/, following in the wake of previous work which has uncovered wide variation in Dutch /r/ realizations while considering the implications for phonology (e.g. Van der Velde and Van Hout 2001; Plug and Ogden 2003; Sebregts and Scobbie 2005). 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. We explore this issue via 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 therefore to describe /r/ as requiring two different categories which differ in both manner and place. But is this phonologization? 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?

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.

15.2 Method

15.2.1 *Participants*

We present data from five 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. Please see Scobbie, Sebregts, and Stuart-Smith (2009) for more technical details of this study. All were bilingual in English, and 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.

The types of systems that were found 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).

15.2.2 *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 digitized at 25Hz with an associated acoustic signal synchronized with a temporal alignment error of at worst ± 30ms. 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). As a prompt, speakers were presented with a picture on screen. 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.

15.2.3 *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

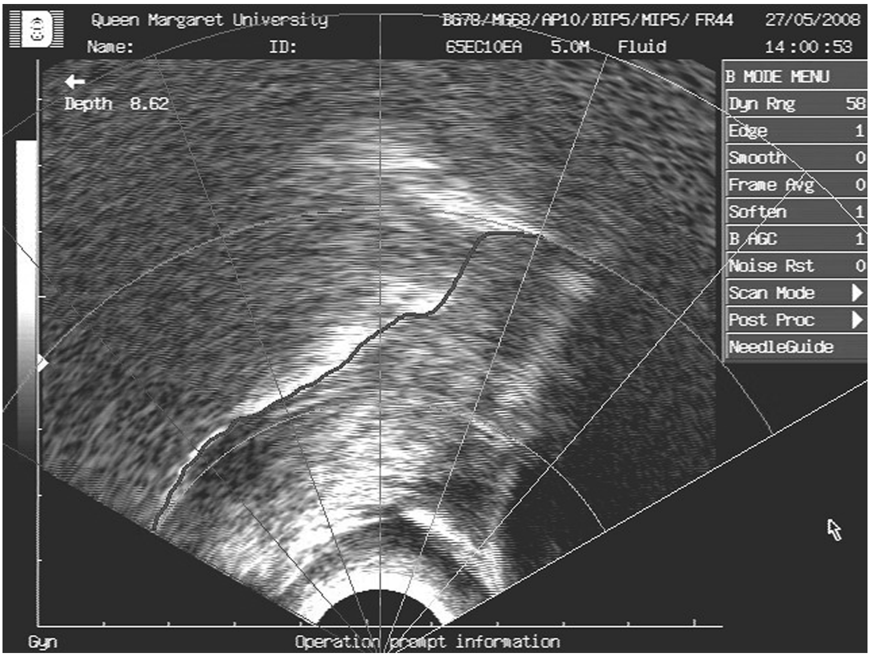

FIGURE 1. Ultrasound Tongue Imaging, with tip and blade to right, root to left. This is a token of a post-alveolar approximant. An analysis curve has been superimposed onto the raw data, at the base of the bright white areas created by reflections from the tongue surface.

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 co-articulation. 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/	*riem*	'belt'
Bare coda:	/ir/	*mier*	'ant'
	/ar/	*schaar*	'scissors'
	/ur/	*boer*	'farmer'
Coda cluster:	/ɔt/ - /ɔrt/	*bot* vs *bord*	'bone' vs 'plate'
	/as/ - /ars/	*kaas* vs *kaars*	'cheese' vs'candle'

15.2.4 *Measurement*

15.2.4.1 *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 a 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 normalized in order to present more direct and qualitative characterization 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 rhoticized part of the voiced part of the rime, immediately before the final consonant. The final consonant could well be co-articulated 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.)

15.2.4.2 *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. Here we have chosen frames judged to be the one containing the most extreme, clearest articulation of /r/. By and large, this frame was at the end of phonation in the transition to silence.

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. Tongue shapes can be qualitatively assigned, based on the types of /r/ constriction proposed by Delattre and Freeman (1968).

15.3 Results

15.3.1 *Impressionistic Results*

Speaker RR sounds highly derhoticized in the coda (Vieregge and Broeders 1993; van den Heuvel and Cucchiarini 2001; Plug and Ogden 2003), especially after /a/, 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.

15.3.2 *Acoustic Results*

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

15.3.2.1 *Durational Analysis* Figure 2 reflects our impression that speaker RR differs from the other subjects in being derhoticized, 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

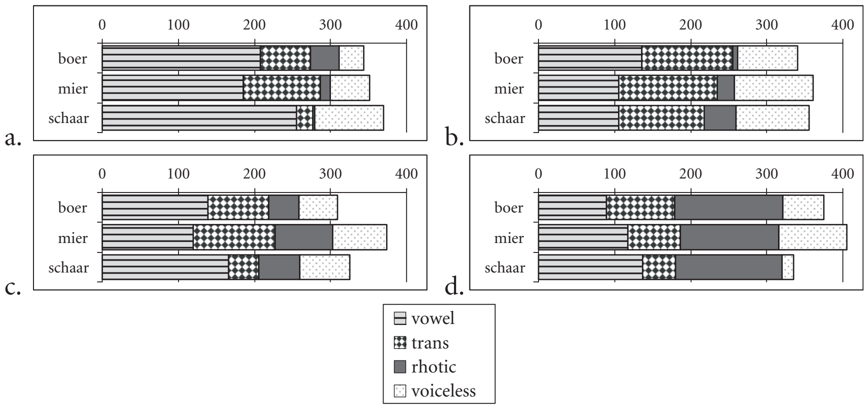

FIGURE 2. Durations (ms) of acoustic events in syllable rime of /r/-final words; speakers a. RR b. UR c. UB1 d. UB2.

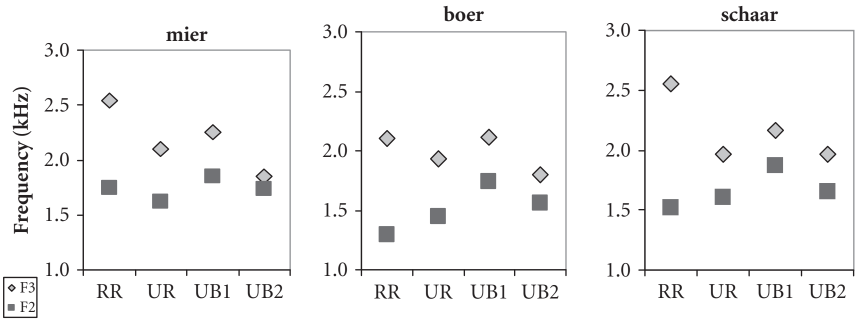

FIGURE 3. Second and third formants during their closest approximation in a rime ending with phonological /r/.

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.

15.3.2.2 *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 derhoticization 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.

Across speakers, there is some consistent co-articulation 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*

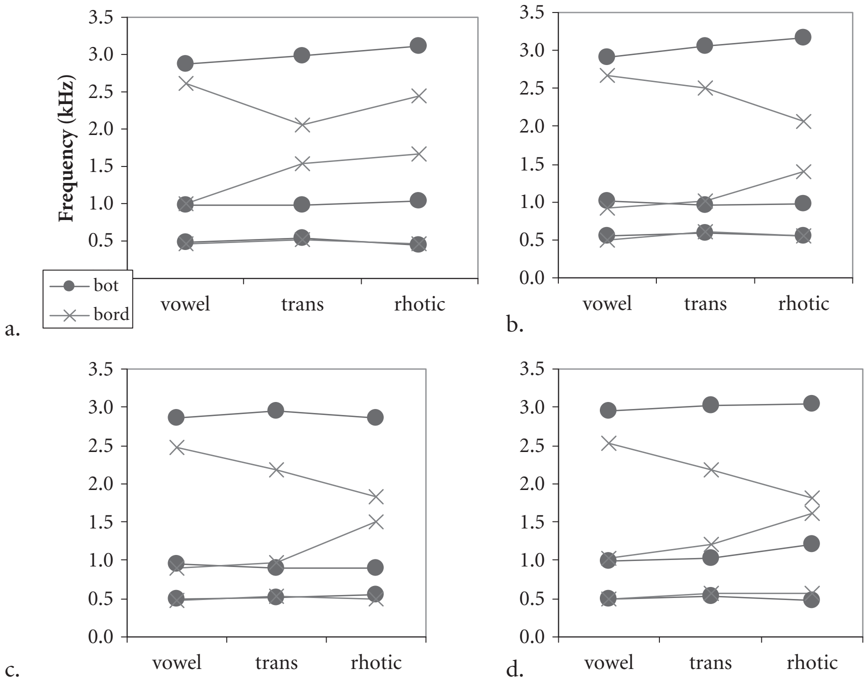

FIGURE 4. The first three formants in a rhotic (crosses: bord) vs rhotic-less (circles: bot) stop-final minimal pair, normalized time; speakers a. RR b. UR c. UB1 d. UB2.

We turn now to the minimal pairs. In Figure 4 and particularly in Figure 6 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 co-articulatory 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 neutralization here in RR's speech, but rather we have shown that the impression of derhoticization 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

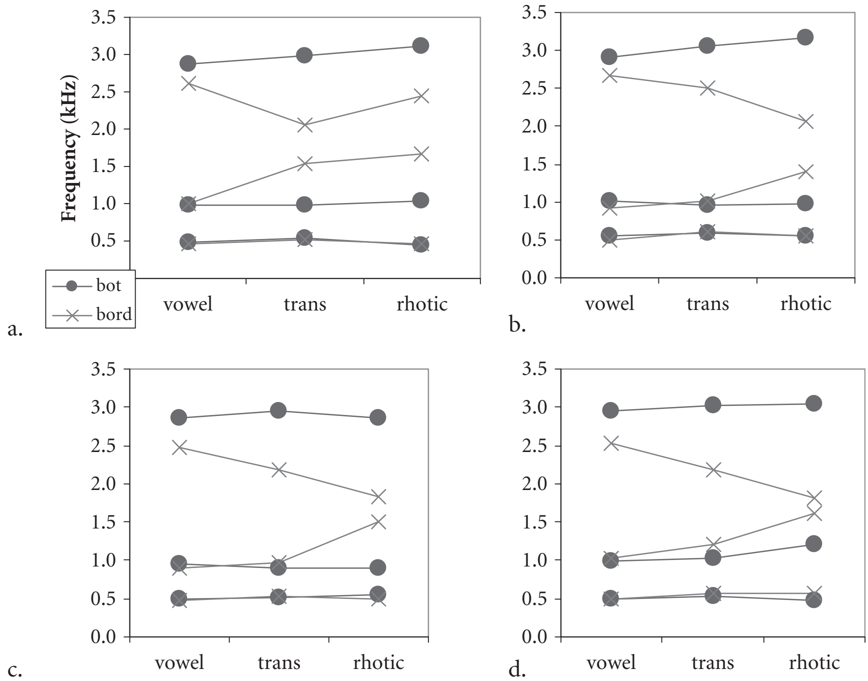

Figure 5. The first three formants in a rhotic (crosses: bord) vs rhotic-less (circles: bot) stop-final minimal pair, normalized time; speakers a. RR b. UR c. UB1 d. UB2. AQ1

average, with individual tokens completely lacking any impressionistic quality of rhoticity at all in the case of the rime /ar/.

15.3.3 *Articulatory Analysis*

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 the articulatory analysis we look at singleton /r/, contrasting the tongue shapes of onsets and codas within speaker. In Figure 7 (Speaker UR) and Figure 8 (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/.)

Both speaker UB1 in Figure 8a and UB2 in Figure 8b show a large onset-coda allophonic difference. They have a post-alveolar approximant coda /r/ which is bunched (tip down), unlike UR (Figure 7) or RR (Figure 10 below)

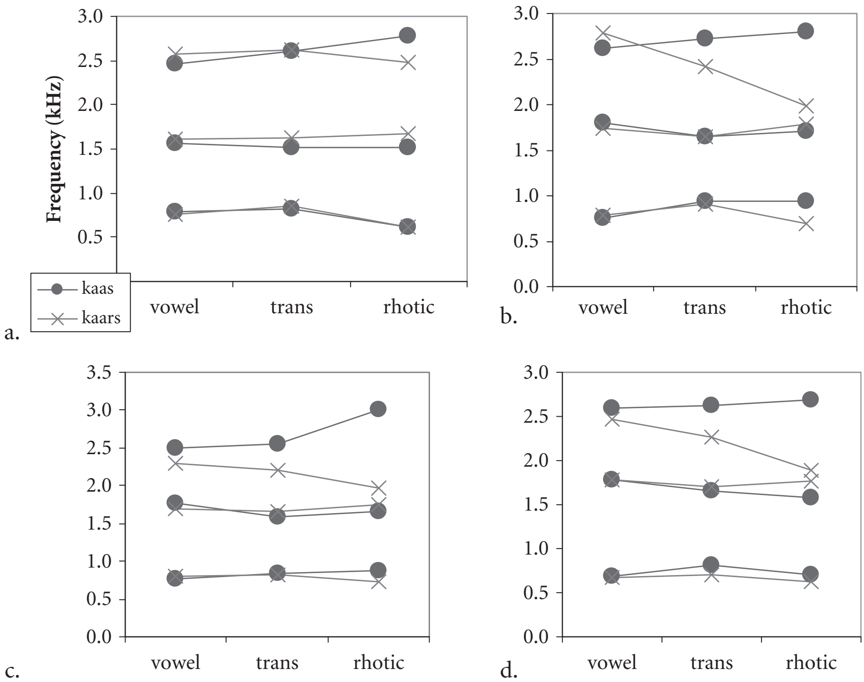

Figure 6. The first three formants in a rhotic (crosses: kaars) vs. rhotic-less (circles: kaas) fricative-final minimal pair, normalised time; Speakers a. RR b. UR c. UB1 d. UB2.

who have a tip-up or retroflex articulation (finally providing the evidence for the five speakers' code names as mentioned in section 15.2.1). Note, however, that in Figure 8a 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.

For speaker RR, who has an approximant onset, Figure **10** shows that articulatory rhoticity in the coda is clear and comparable in strength to the onset, despite both impressionistic and acoustic coda derhoticization. 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 such a strong impression of rhoticity as it does in the onset. Of particular interest is the clearly visible but acoustically covert tip raising in *schaar* (Figure 10), the rime of which is nearly monophthongal (Figure 3).

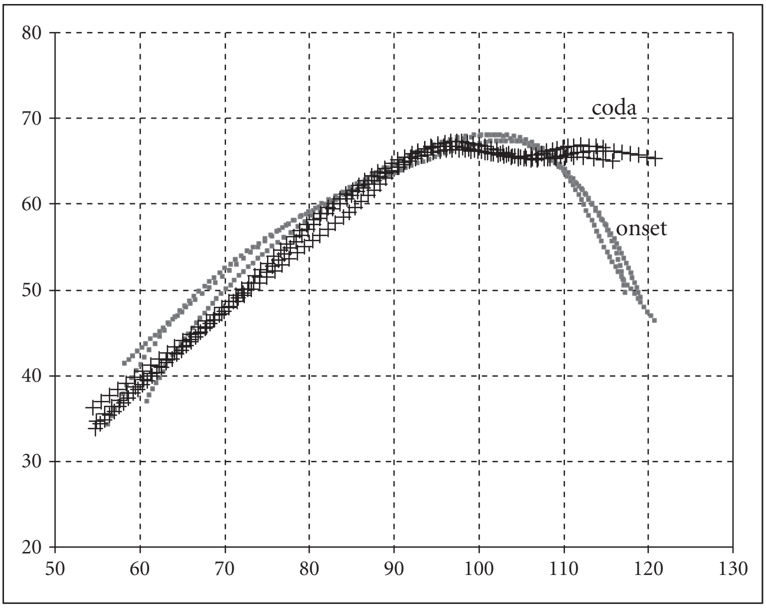

FIGURE 7. Extracted tongue surface contours from the three tokens of speaker UR's onset /ri/ (crosses) and coda /ir/ (small squares), showing broadly comparable pharyngeal contours (on the left of the image) but with clear anterior tip raising (on the right) in the coda but not in the onset. Horizontal and vertical measures are in mm from an arbitrary origin. Subsequent figures follow these same conventions.

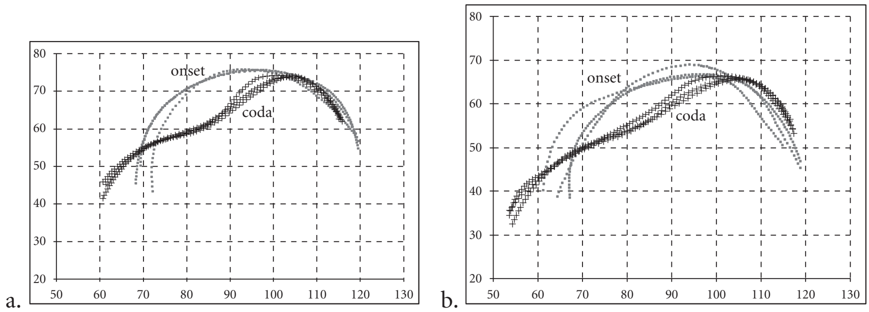

FIGURE 8. Extracted tongue surface contours from a. UB1 and b. UB2. Both show a near semi-circular shape for the uvular trill in onset /r/ vs a clear double articulation for the post-alveolar approximant coda /r/. The latter has a retracted tongue root, a tip-down post-alveolar constriction, and a saddle in between.

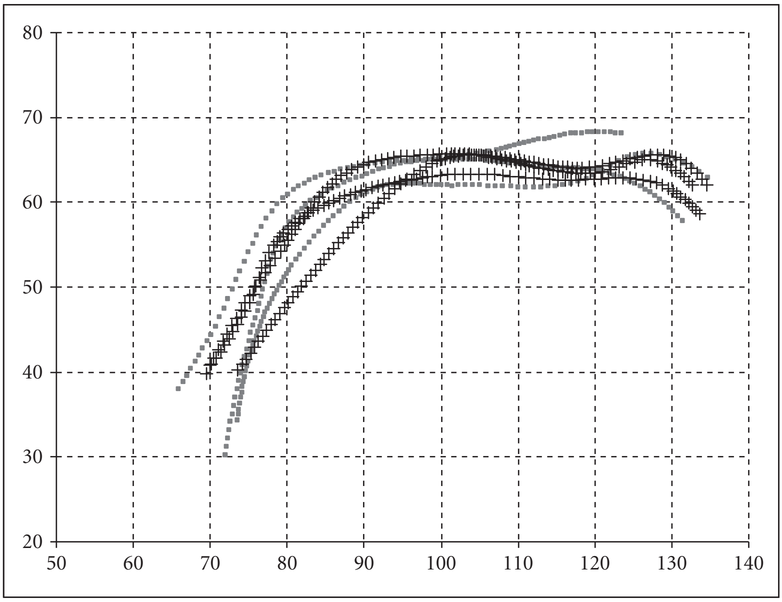

FIGURE 9. Extracted tongue surface contours from the three tokens of speaker RR's onset /ri/ (crosses) and coda /ir/ (small squares), showing comparable retroflexion in both, with greater token-to-token variation than other speakers.

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' is most appropriate in the context of /a/, since /i/ and /u/ have centring and slightly rhoticized 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 (Figure 9), we looked at the /r/-ful

FIGURE 10. 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.

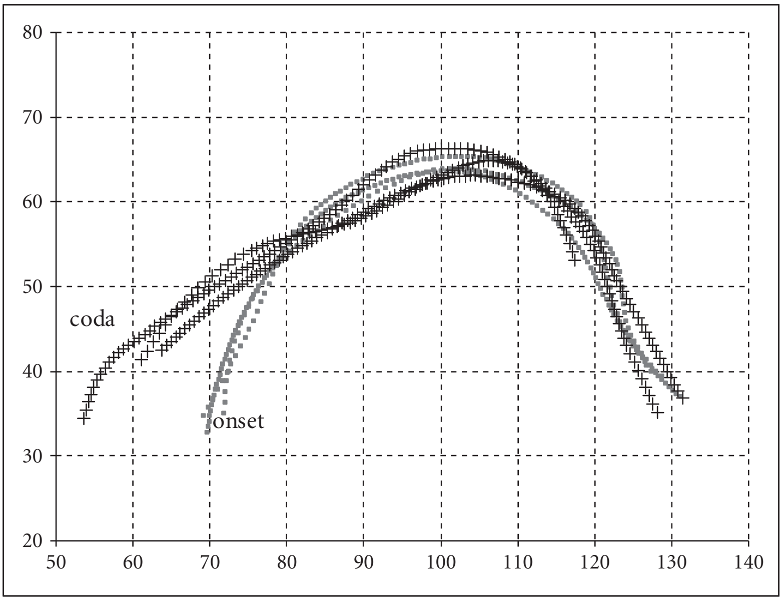

FIGURE 11. Coda uvular trill /r/ from UU with a pharyngeal retraction not present in the onset.

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 co-articulation 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 co-articulated. 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 derhoticization, 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.

Finally, consider speaker UU (Figure 11), 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/

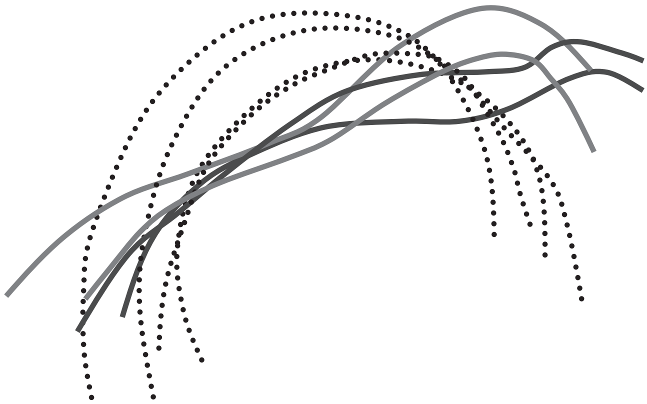

Figure 12. Overlaid tongue curves from 'boer', showing consistency in /u/ (dotted lines) and variation in /r/ (solid lines) with two bunched tip-down (UB1, UB2) and two tip-up slightly retroflex (RR, UR) post-alveolar approximants.

vowel in *schaar*. The same is true for UB1. UB2 shows much more co-articulation 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*).

The clear division into tip up (UR, RR) and bunched (UB1, UB2) approximants can be emphasized by informally overlaying all the speakers (Figure 12). 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: the two types of /r/ appear quite distinct and comparable to the patterns presented by Delattre and Freeman (1968).

15.4 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. Otherwise the allophony would be phonetic, where a single segmental specification is realized differently by phonetic implementation on the basis of the difference in higher structure.

The phonetic data presented here are tantalizing, 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 derhoticized (cf. similar cases in Plug and Ogden 2003), apparently even deleting /r/ in some tokens. Her deletions are probably variants due to gestural weakening (in the sense of Browman and Goldstein 1992). However, the articulatory data reveals that in every case things are 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 11). 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.* forthcoming), but this is something that must be investigated further. All four approximants have some degree of pharyngealization, 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's (1985) 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. 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-phonologization. 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 post-alveolar 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 post-alveolar 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 post-alveolar 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 derhoticization 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. Before silence, word-final /r/ seems to involve some kind of gestural delay rather than gestural weakening, but not any categorical phonological deletion. Such covert rhotic articulations have been further evidenced in recent work on Scottish English (Lawson, Stuart-Smith, and Scobbie 2008; Scobbie, Stuart-Smith, and Lawson 2008; Scobbie, Sebregts, and Stuart-Smith 2009), and Scobbie *et al.* (2008) explore the implications of such data: /r/ derhoticization is socially-distributed in Scottish English (Romaine 1979; Stuart-Smith 2007). Our hypothesis is that the anterior constriction for /r/ is made by RR, but close to and often after the offset of phonation. At most, she generates a very weak voiceless excitation of the rhotic constriction.

In connected speech and word-internally, further variants appears to occur. When /r/ is immediately followed by an anterior lingual consonant within the same word, the anterior constriction appears to be very weak or even absent as an independent consonant. The following consonant can be, however, slightly rhoticized. In pairs like *kaas* vs *kaars*, the contrast seems very weak indeed, so 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.

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 Cucchiarini 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 realized 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 glottalization intervenes, arguing against phonological resyllabification (Scobbie and Pouplier, under review).[2] If the following word begins with a voiceless /p/ (*de boer poetst*), the acoustic

[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 and Broeders (1993) and Van de Velde (1996), some /r/s are transcribed as 'zero' on the basis of purely acoustic data.

[2] Even so, gestural delay might give some insight into the diachronic origin of floating phonological features and external sandhi 'resyllabification'.

and impressionistic story is still that RR is derhoticized. However, unlike the other phrase-medial cases above involving gestural reduction, there can be, just like in the pre-pausal case, a strong rhotic gesture, masked by the silence of /p/.

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. derhoticization) count as a target and therefore as a representation of phonological structure at 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 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 (1998), 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.

To conclude, 'the' phonetics-phonology interface is multifaceted. The data presented here suggest a complex interplay between 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). This is typical of detailed phonetic data (whether from articulatory, acoustic, or perceptual research), which is why studies in laboratory phonology (Pierrehumbert *et al.* 2000) may 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-categorized, segmental transcriptions.

Are uvular trill and coronal approximant allophones of Dutch /r/ discretely different? If so, how do they emerge as allophones of the same phoneme? The first answer is yes **and** no. For the second, we think a phonetic explanation is more likely to be successful. However, it is not clear from our small study whether it makes sense to allocate the more discrete aspects of allophony exclusively to phonetics or phonology. The structural conditioning factors we have examined are discrete, so even phonetic allophony can appear to involve categorical distinctions. What is just as important as the clear differences between trills and approximants are the hidden details of secondary articulations. Our initial data appear to challenge both phonetic and phonological explanations of coda weakening while providing some rationale for a phonetic continuity between uvular trill and post-alveolar approximant, thus providing insight into what appears initially to be a case of straightforward phonological allophony. We conclude that some fundamental phonological questions need to be addressed through large-scale studies which provide detailed data about phonetics, including speech production, as part of a renewed commitment to the empirical underpinnings of our field.

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