THE STORY OF /r/ IN TWO VOCAL TRACTS

Thomas J. Magnuson

Department of Linguistics, University of Victoria, Victoria, BC, Canada
thomasm@uvic.ca

ABSTRACT

Since even before Mona Lindau's Story of /r/, the search for a single phonetic (acoustic or articulatory) characteristic which defines rhotics as a class has met with little success [15]. With such a phonetic characteristic being elusive, the model which emerged for the study of rhotics was one of 'family resemblances' [15, 16] wherein rhotic speech sounds were linked - but not unified - by a patchwork of phonetic parameters. The study of such parameters/resemblances, and of rhotics in general, was additionally grounded in a single-tube-single-source conception of the vocal tract. In light of a new way of conceiving of the vocal tract as a two-part system [8, 9], however, it is necessary to re-think our model for studying rhotics to accommodate the contribution of the laryngeal/pharyngeal vocal tract (LPVT) to the system of family resemblances described by Lindau. This paper proposes a model (Fig. 2) of rhotic association parameters which builds on Lindau's 1985 model by incorporating three components of the LPVT: *aryepiglottic fold trilling*, *pharyngeal modification*, and *vocal fold vibration*.

Keywords: rhotics, pharyngeal constriction, story of /r/, laryngeal/pharyngeal vocal tract, liquids.

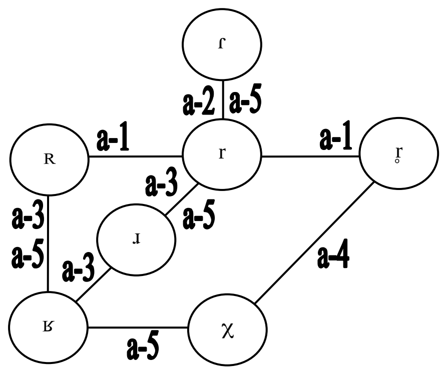
1. INTRODUCTION

The aim of this paper is to revise the family resemblances model for the study of rhotic liquids by accounting for the contribution of the LPVT [8, 9] to their production. It bears mention that this aim is a preliminary theoretical step toward grounding future empirical work: the goal here is not to present direct evidence or measurement of the LPVT's contribution to rhotics as such, but rather to suggest directions for subsequent research whereby such evidence might be obtained.

1.1. The family resemblances model

At the heart of the family resemblances model is the notion that, instead of their being unified as a class of sounds by some single phonetic trait, rhotics are related to one another in a chain of overlapping parameters of association [15, see Fig. 1]. That is, trills and flaps are related by the parameter *closure duration* while trills and approximants are related by the *presence of formant frequencies*. Flaps and approximants, in turn, are indirectly related to one another based on their common connection with trills.

Figure 1: Lindau's 1985 model of rhotic parameter relations [15:167]



a-1	Pulse pattern (trill)
a-2	Closure duration
a-3	Presence of formants (sonorant)
a-4	Presence of noise
a-5	Spectral energy distribution (place)

Missing from the family portrait in Fig. 1, though, is any mention of a laryngeal/pharyngeal component – even voicing – that could potentially add to the linkages among the family of rhotics.

1.2. The dual vocal tract model

The vocal tract has traditionally been viewed as a single long tube that moulds glottal pulses into speech: the glottis is the (single) source, and the vocal tract is the filter [e.g. 2, 5]. In contrast to this single-tube-single-source model, Edmondson & Esling [8] propose a two-tract model wherein the oral vocal tract (OVT) and the LPVT are separate. The LPVT is in turn viewed as a series of six valves (Table 1) whose functioning not only affects the resonant qualities of the rest of the entire vocal tract but also *produces* sound in concert with the vocal folds (V1).

Aryepiglottic (AE) fold trilling is an additional sound source brought about through compression of the arytenoids over the glottis (V3). Auditorily, the effect of this is the growl-like voice quality associated with some singing and expressive speech styles [19, 20]. In the model of rhotic association parameters proposed here, the working of any combination of Valves 3, 4, and 6 to either expand or contract the pharynx is referred to as *pharyngeal modification*, discussed further in §2.

Table 1: Valves of the LPVT, adapted from [8].

Valve	Function
V1	Glottal vocal fold ad/abduction
V2	Incursion of ventricular folds onto V1
V3	Laryngeal constriction, AE compression
V4	Epiglotto-pharyngeal constriction
V5	Laryngeal raising & lowering
V6	Pharyngeal narrowing

It should be noted that although engagement of V4 and V6 entails the action of V3, or laryngeal constriction in the general sense, the AE folds are not necessarily engaged to the extent of producing a trill [8].

2. AN UPDATED FAMILY PORTRAIT

The model presented in Fig. 2 differs from Lindau's arrangement of association parameters (Fig. 1) chiefly in its division of the vocal tract into oral and laryngeal/pharyngeal components. Insofar as all of the rhotics shown in Fig. 2 primarily involve some configuration of the tongue in the oral cavity, they are listed in the OVT. The LPVT is home to three additional parameters: *AE trilling*, *pharyngeal modification*, and *vocal fold vibration*. The first and last of these are sound sources which may or may not coincide with one another; indeed AE trilling can be considered as an optional voice quality applicable to any of the rhotics in Fig. 2.

Pharyngeal modification refers to dynamic adjustments made to the shape of the pharyngeal resonating cavity through the workings of one or more of the valves listed in Table 1. One of the principle valves involved in this is V4, or *epiglotto-pharyngeal constriction* [8], whereby the epiglottis and back of the tongue retract into the mid- to lower pharyngeal cavity [see also 6, 9, 17 for illustration]. Different acoustic observations may be made depending on where modification occurs in the pharynx: constriction at the bottom of the pharynx yields the lowering of F3 typical of [ɹ] at the same time as F2 is raised [6, 7, 15, 16]. The opposite pattern can be seen at the top of the pharynx: F3 raises as a result of the shorter oral cavity, while F2 lowers reflecting a larger pharyngeal cavity [6, 7]. Hence the acoustic thumbprint of pharyngeal modification is variable: the 2nd and 3rd formants may be either close together as for English [ɹ] or far apart as for Southern Swedish [ʁ] [15].

Place in the oral vocal tract is analogized in Fig. 2 by branches, with labials to the left and uvulars to the right. Manner, or rather degree of articulatory stricture, is generalized along the vertical axis with the proviso that while taps and trills do not necessarily differ in terms of degree of stricture, they do differ in terms of sustainability of their articulation. Thus, Lindau's *pulse pattern* and *closure duration* parameters [15] are reinterpreted by making the distinction between *momentary closure* (= taps, trills) and *sustainable articulation* (= all but taps).

The placement of the two representative rhoticized vowels at the bottom of Fig. 2 reflects the idea of vowel *retraction* (as opposed to backness) proposed as the vocalic extension of the dual vocal tract model [9]. In this view, openness of the jaw is compatible with the engagement of the LPVT valves, making the addition of a laryngeal/pharyngeal component in their articulation more likely [9]. The parameters *presence of formants* and *presence of noise* are preserved from Lindau's model but I propose that these (and all the other) parameters can overlap. That is, just as devoiced taps and trills may have some degree of frication noise [12], some voiced fricatives and lenited flaps may well retain formant patterns from neighbouring vowels.

It also bears mention that there is no attempt here to assert that any parameter in the model is not essentially gradient. That is, instead of a binary on-off setting for pharyngeal modification or AE trilling for a given rhotic, it is more reasonable to talk about rhotics, and indeed laterals, as having a greater or lesser *propensity* to involve either LPVT component depending on where and how they are articulated.

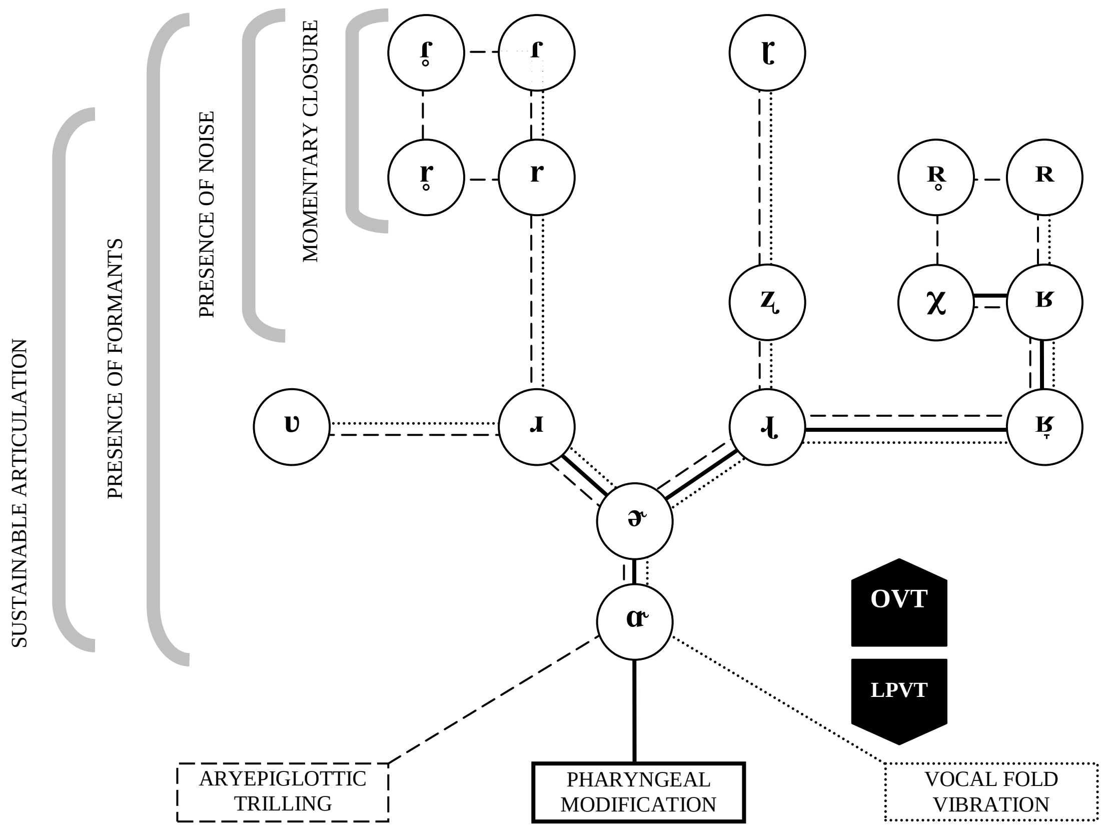


Figure 2: Interrelations among some rhotic liquids and their connection with the LPVT

2.1. Drawing the pharyngeal modification line

Claiming that all of the rhotics' association parameters are gradient brings about the problem of deciding which of the rhotics to associate by the solid bold line indicating pharyngeal modification. Whereas in stop production we have voice onset time to integrate the OVT and the LPVT, no established analogue exists for the description of the extent to which the shape of the pharynx is altered: nothing to pin a negative or positive integer on. Because of the need to include rhotics in the integration of the oral and laryngeal vocal tracts, I tentatively propose drawing the line between rhotics for which visual articulatory evidence (ultrasound, MRI, et cetera) is available. X-ray tracings of 'back' vowels [17] and schwar [15] show incursion by the tongue back/epiglottis into the pharyngeal cavity. More recent speech therapy work involving visual feedback via ultrasound also suggests that patients generalize the tongue root position for prolonged [ɹ] to that of [ɝ] [3, 4]. MRI research [16] on the Tamil retroflex rhotic [ɻ] similarly shows the tongue back as modifying the shape of the pharyngeal cavity, confirming other work which has identified a pharyngeal constriction in the production of both 'bunched' and 'tip-up' [ɹ] [1, 22]. As for the uvular rhotic approximant [ʁ̞], it is attested as an intervocalic allophone of German /ʁ/ [13, 21], and also shown by Delattre's x-ray tracings [7] as involving the tongue-back intruding into the pharyngeal cavity. Although pharyngeal modification can be motivated as a parameter of association among rhotic vowels and the approximants [ɹ, ɻ, ʁ̞], the question is open as to whether the same line can be drawn to the phonologically rhotic labial variants [{ʋ, β̞}] attested in British English [10].

Among the fricative rhotics, Delattre's [6] cineradiographic observations of a circular motion into the mid-pharynx by the back of the tongue for [ɹ] are also characteristic of the fricative [ʁ]. And, while more research is needed to confirm the degree of pharyngeal constriction involved, the voiceless allophone [χ] in Parisian French presumably involves an analogous pharyngeal component. Beijing Mandarin /r/ (= [ʐ]) is more troublesome: while Gick et al.'s ultrasound study [11] showed a 'tongue-backing' gesture, it only occurred post-vocalically.

Lindau's spectrograms of the Southern Swedish uvular [ʀ] and apical [r] trills show a clear formant pattern between contacts, with F2 and F3 very far from each other. While this arguably motivates pharyngeal modification on acoustic grounds [6], I exclude these in the present model barring articulatory evidence of the pharyngeal cavity being altered. Similarly, whether and to what degree pharyngeal modification is involved in the production of the other trills and taps in Fig. 2 is left as a topic for future empirical articulatory research. The pharyngeal components in rhotics discussed here differ from pure pharyngeals in that they involve a concomitant (primary) oral configuration. In the case of pure pharyngeals, the pharyngeal is the primary articulation.

3. FUTURE RESEARCH DIRECTIONS

Although there has been much kinematic work done on the oral component of rhotics [12, 16, 22] further articulatory research that focuses explicitly on the behaviour of the pharyngeal cavity during the production of all rhotic liquids is needed in order to better understand how rhotics – and for that matter lateral liquids – are related by parameters which originate beyond the oral cavity. The model proposed here provides a framework for that research by explaining how the laryngeal articulator is poised to add pharyngeal colouring to rhotics (and rhoticized vowels) in addition to their inherent oral properties.

4. ACKNOWLEDGEMENTS

I would like to thank the faculty, staff, and graduate students of the University of Victoria's Linguistics Dept. for their guidance and encouragement. In particular, the advice and comments of Drs. John Esling and Hua Lin, and the help of Allison Benner, Izabelle Grenon, Soo Youn Ham, and Scott Moisik are greatly appreciated as are the comments of two anonymous reviewers. Any and all errors are entirely my own.

5. REFERENCES

[1] Alwan, A., Narayanan, S., Haker, K. (1997). Toward articulatory-acoustic models for liquid approximants based on MRI and EPG data. Part II. The rhotics. *J. Acoust. Soc. Am.* 101(2), 1078–1089.

[2] Ball, M.J., Rahilly, J. 1999. *Phonetics: the Science of Speech*. New York: Oxford.

[3] Bernhardt, B., Gick, B., Bacsfalvi, P., Ashdown, J. (2003). Speech habilitation of hard of hearing adolescents using electropalatography and ultrasound as evaluated by trained listeners. *Clinical Linguistics & Phonetics* 17(3), 199–216.

[4] Bernhardt, B., Gick, B., Bacsfalvi, P., Adler-Bock, M. (2005). Ultrasound in speech therapy with adolescents and adults. *Clinical Linguistics & Phonetics* 19(6), 605–617.

[5] Borden, G.J., Harris, K.S., Raphael, L.J. 2002. *Speech science primer: Physiology, acoustics, and perception of speech*, 4th Edition. Baltimore, MD: Lippincott Williams & Wilkins.

[6] Delattre, P., Freeman, D.C. 1968. A dialect study of American *r*'s by x-ray motion picture. *Linguistics* 44, 29–68.

[7] Delattre, P. 1971. Pharyngeal features in the consonants of Arabic, German, French, Spanish, and American English. *Phonetics* 23, 129–155.

[8] Edmondson, J.A., Esling, J.H. 2006. The valves of the throat and their functioning in tone, vocal register and stress: Laryngoscopic case studies. *Phonology* 23, 157–191.

[9] Esling, J.H. 2005. There are no back vowels: The laryngeal articulator model. *Canadian Journal of Linguistics* 50, 13–44.

[10] Foulkes, P., Docherty, G.J. 2000. Another chapter in the story of /r/: 'Labiodental' variants in British English. *Journal of Sociolinguistics* 4(1), 30–59.

[11] Gick, B., Campbell, F., Oh, S., Tamburri-Watt, L. 2006. Toward universals in the gestural organization of syllables: A cross-linguistic study of liquids. *Journal of Phonetics* 34, 49–72.

[12] Jesus, L.M.T., Shadle, C.H. 2005. Acoustic analysis of European Portuguese uvular [χ, ʁ] and voiceless tapped alveolar [ɾ̥] fricatives. *Journal of the International Phonetic Association* 35(1), 27–44.

[13] Kohler, K. 1999. Illustrations of the IPA: German. *Handbook of the International Phonetic Association*. Cambridge Univ. Press, 86–89.

[14] Ladefoged, P., Maddieson, I. (1996). *The Sounds of the World's Languages*. Oxford: Blackwell Publishers.

[15] Lindau, M. 1985. The story of /r/. In: Fromkin, V.A. (ed.), *Phonetic Linguistics: Essays in honor of Peter Ladefoged*. Orlando, FA: Academic Press, 157–168.

[16] Narayanan, S., Byrd, D., Kaun, A. 1999. Geometry, kinematics, and acoustics of Tamil liquid consonants. *J. Acoust. Soc. Am.* 106 (4-1), 1993–2007.

[17] Perkell, J.S. 1969. *Physiology of Speech Production: Results and Implications of a Quantitative Cineradiographic Study*. Cambridge, MA: MIT Press.

[18] Recasens, D., Pallarès, M.D. 1999. A study of /ɾ/ and /r/ in the light of the 'DAC' coarticulation model. *Journal of Phonetics* 27, 143–169.

[19] Sakakibara, K., Fuks, L., Imagawa, H., Tayama, N. (2004). Growl voice in ethnic and pop styles. In: *Proc. ISMA 2004*. Nara, Mar. 2004.

[20] Sakakibara, K., Kimura, M., Imagawa, H., Niimi, S., Tayama, N. (2004). Physiological study of the supraglottal structure. In: *Proc. ICVPB 2004*. Marseille, Aug. 2004.

[21] Schiller, N. (1995). The character of r-sounds: Articulatory evidence for different reduction processes with special reference to German. In: *Proc. ICPhS XIII*. Stockholm, Aug. 1995.

[22] Westbury, J.R., Hashi, M., Lindstrom, M.J. 1998. Differences among speakers in lingual articulation for American English /ɹ/. *Speech Comm.* 26, 203–226.