Why rhoticity is on everyone's lips: Accounting for the labial gesture in English /r/

The approximant consonant /r/ has been described as one of the most complex phones in the English language [1]. Articulatory variation has been widely observed, particularly with regards to tongue body shapes, which range from tip down bunched to curled up retroflex [2, 3]. Despite the array of articulatory variation detailed in the literature, notably in rhotic varieties of English, the acoustic profile for /r/ remains remarkably stable; the most salient feature being a very low F3. Articulatory-acoustic models have associated the low F3 with the front cavity, i.e. between the palatal constriction and the lips [4, 5]. Extending the front cavity - through a more posterior palatal constriction, the addition of a sublingual space, or increased lip protrusion - may contribute to the lowering of F3. As bunched /r/ has a low tongue tip, it has negligible sublingual space, contrary to retroflex /r/. [5] posit a "trading relation" between the existence of a sublingual space and the placement of the palatal constriction: bunched /r/ was more posterior than retroflex. A similar trading relation may be possible for lip protrusion. However, there is no study to date that investigates this idea.

Although it is generally agreed that /r/ may be accompanied by a labial constriction, the lips tends to be overlooked, and their precise contribution is unknown. The lips are of particular interest in the English spoken in England (Anglo-English) because labiodental variants [ʋ], which supposedly lack an obvious tongue body gesture, are becoming increasingly common [6]. We present acoustic and articulatory data (via ultrasound tongue imaging and lip videos) from 24 Anglo-English speakers which suggest that lip protrusion allows speakers to maintain a stable acoustic output across different tongue configurations. We observe significantly more lip protrusion in bunched tongue configurations than retroflex ones.

Furthermore, evidence from hyperarticulated productions of /r/ reveals that speakers actively control articulatory parameters to enhance the discriminability of /r/, notably via increased lip protrusion and retroflexion. We engaged speakers in error resolution with a simulated "silent speech" recognition programme where /r/ was "incorrectly" identified as /w/ or /l/ one third of the time. As a result, speakers adapted their productions of /r/ to obtain significantly lower F3 values. Regardless of tongue shape, lip protrusion significantly increased in hyperarticulation. However, statistical models still predict more lip protrusion in bunched than in retroflex /r/. Retroflex /r/ can undergo further enhancement through increased curling back, thus increasing the size of the sublingual cavity. We suggest that as this strategy is not available to bunchers, lip protrusion is used as an alternative means to increase the size of the front cavity, and therefore the discriminability of /r/.

Our results indicate that lip protrusion is an articulatory mechanism speakers employ to enhance rhoticity. As a result, the spread of labiodental variants may be a direct consequence of the perceptual prominence of lips: the labial gesture is perceptually salient enough to supersede the lingual one. Our future research will consider to what extent visual cues may influence the perception of /r/.

Key words: lips; Anglo-English; hyperarticulation; ultrasound

[1] M. Adler-Bock, B. M. Bernhardt, B. Gick, and P. Bacsfalvi, "The use of ultrasound in remediation of North American English /r/ in 2 adolescents," *American Journal of Speech-Language Pathology*, vol. 16, no. 2, pp. 128–139, 2007.

[2] P. Delattre and D. C. Freeman, "A dialect study of American r's by x-ray motion picture," *Linguistics*, vol. 6, no. 44, pp. 29–68, 1968.

[3] M. K. Tiede, S. E. Boyce, C. K. Holland, and K. A. Choe, "A new taxonomy of American English /r/ using MRI and ultrasound," *The Journal of the Acoustical Society of America*, vol. 115, no. 5, pp. 2633–2634, 2004.

[4] A. Alwan, S. Narayanan, and K. Haker, "Toward articulatory-acoustic models for liquid approximants based on MRI and EPG data. Part II. The rhotics," *The Journal of the Acoustical Society of America*, vol. 101, no. 2, pp. 1078–1089, 1997.

[5] C. Y. Espy-Wilson, S. E. Boyce, M. Jackson, S. Narayanan, and A. Alwan, "Acoustic modeling of American English /r/," *The Journal of the Acoustical Society of America*, vol. 108, no. 1, pp. 343–356, 2000.

[6] G. Docherty and P. Foulkes, "Variability in (r) production-instrumental perspectives," *'R-atics: Sociolinguistic, phonetic and phonological characteristics of /r/. Etudes & Travaux 4*, pp. 173–184, 2001.