

Using ultrasound tongue imaging to study the transfer of covert articulatory information in coda /r/

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Several decades of investigation have established that there is an auditory dichotomy for postvocalic /r/ in the Scottish Central Belt, (Romaine 1978; Speitel and Johnston 1983; Stuart-Smith 2003; Stuart-Smith 2007) and beyond, e.g. in Ayrshire (Jauriberry, Sock et al. 2012). Weak rhoticity is a feature of working-class (WC) speech, strong rhoticity is associated with middle-class (MC) Central Belt speech.

Ultrasound tongue imaging (UTI) has identified articulatory variation that contributes to this auditory dichotomy; underlyingly coda /r/ in MC and WC speech involves radically different tongue shapes (Lawson, Scobbie et al. 2011b) and tongue gesture timings (Lawson, Scobbie and Stuart-Smith 2015). This articulatory variation has gone unidentified, despite decades of auditory and acoustic analysis (Romaine 1978; Speitel, Johnston 1983; Stuart-Smith 2003; Stuart-Smith, Timmins et al. 2007). UTI revealed that bunched /r/ variants (see Delattre & Freeman 2009) are prevalent in WC speech (Lawson, Scobbie and Stuart-Smith 2014) while WC speech shows a prevalence of tongue tip/front-raised /r/ with delayed anterior gestural maxima that can occur after the offset of voicing or during the articulation of a following labial consonant, e.g. in *perm*, *firm*, *verb* etc. The fact that apparently covert articulatory variants pattern with speaker social class, suggests that this covert articulatory variation in /r/ production is perceptible or recoverable.

We present results of a UTI-based speech-mimicry study that investigates whether these types of subtle articulatory variation can be copied if the speaker is presented with audio only and asked to mimic what they hear. We investigate whether they use different articulatory strategies to achieve the strong rhotic quality found in MC /r/ by e.g. by either bunching or retroflexing their tongue, and whether they misinterpret delayed, weakly audible, /r/ gestures as deletion of /r/.

We recruited thirteen female Central-Belt Scottish speakers to take part in the mimicry study (8 MC aged 13-23 and 5 WC aged 13-22), as females were found to produce the most extreme articulatory variants in their social-class groups (see Lawson et al 2014). Baseline articulatory information on their /r/ production was gathered from audio-ultrasound word-list recordings containing 23 (C)Vr and (C)VrC words such as *pore*, *farm*, *ear*, *herb* etc., plus 55 distractors. All MC participants used bunched /r/ variants in baseline condition. All WC participants used variants that involved raising the tongue front or tip in baseline condition.

Audio stimuli were 82 nonsense-words extracted from the female-speech section of an audio-ultrasound corpus of adolescent speech, collected in Glasgow in 2012. Nonsense words were used to avoid speakers normalizing towards their habitual production of a word. There were 24 /r/-ful nonsense words, randomized in the audio stimuli: (Mimic A) 12 with front/tip-up /r/s with a delayed /r/ gesture and (Mimic B) 12 with bunched /r/ with an early /r/ gesture. The rest of the stimuli (58 tokens) were distractors. Intensity of the audio stimuli was scaled to a mean 70dB using Praat (Boersma & Weenink 2013). Participants were asked to mimic the audio stimuli as closely as possible, “as if they were an echo”.

Analysis showed a range of /r/-mimicking behaviours, the most common of which were (a) no modification of tongue shape from the baseline to the mimicry conditions and (b) modification from the speaker’s baseline /r/ (i.e. tip up to bunched, or bunched to tip up), but no differentiation between the tongue shape used in the Mimic A and Mimic B conditions. (c) Two of the participants successfully copied the underlying tongue shapes of the audio stimuli on a token by token basis with high levels of accuracy, resulting in distinct tongue shapes for the Mimic A and Mimic B conditions. Participants who used tip up /r/ in baseline did not attempt to mimic bunched /r/ stimuli by retroflexing their tongues, suggesting that the underlying bunched /r/ is perceptible and distinguishable from a retroflex. A small number of weakly /r/-ful stimuli were mimicked with no /r/ gesture by WC speakers in the study, but in most cases, speakers

produced an /r/ gesture when they mimicked weakly /r/-ful audio stimuli, which suggests that cues indicating rhoticity persist in the audio signal (see also Lennon 2013).

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