http://dx.doi.org/10.17959/sppm.2020.26.3.487

Retroflection or retraction? Phonetic variability in pre-rhotic coronal stops in English

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Sung, Jae-Hyun. **2020**. **Retroflection or retraction? Phonetic variability in pre-rhotic coronal stops in English.** *Studies in Phonetics, Phonology and Morphology* 26.3. 487-501. Pre-rhotic coronal obstruents in English are prone to various phonological changes, represented by s-retraction as in *street* or t/d-retraction as in *tree* or *dream*. Based on the previous findings that morphological structures and lexical frequency play critical roles in many coarticulatory processes, this study investigates whether the degree of retroflection or retraction before /ɹ/ is influenced by different morphological structures or lexical frequency. Comparisons of tongue contours from seven American speakers show that different morphological structures are not at play in articulatory patterns, but that high-frequency words and phrases, albeit weakly, result in greater degrees of retroflection represented by articulatory posterity, mostly for /d/. Furthermore, the gestural patterns of various morphological and frequency conditions are highly individualized. **(Kongju National University, Assistant Professor)**

Keywords: retroflection, retraction, pre-rhotic coronal stops, articulation, ultrasound imaging

1. Introduction

While lexicalized phonological processes tend to be rule-governed and yield categorial patterns, post-lexical processes result in a great deal of phonetic variability across speakers, items, and contexts (Zsiga 1993, 1995, 2000; Bush 1999, 2001; Kochetov 2002; Ernestus et al. 2006; Yun 2006, 2012; Myers and Li 2009 among many). For example, in English, coronal stops before a palatal glide across a word boundary, as in ‘meet you’ or ‘would you’, undergo overt palatalization, realized as ‘mee[ʧ] you’ and ‘woul[ʤ] you’, but it is considered an optional process, which allows some speakers to pronounce them as ‘mee[t] you’ and ‘woul[d] you’. Among many well-known post-lexical processes including the aforementioned coronal palatalization, this study focuses on pre-rhotic coronal stops, represented by ‘tree’

phonetically realized as [ʧɹii] and 'dream' as [ʤɹim], and investigates phonetic variability shown in articulatory gestures produced by young American speakers using ultrasound imaging. The present study is one of the few attempts to examine the articulatory patterns of a phonological process that does not seem to yield systematic variation.

Pre-rhotic coronal obstruents have been spotlighted in several previous studies. One of the well-known processes with coronal obstruents is s-retraction (Baker et al. 2011). S-retraction refers to the change from /s/ to [ʃ]-like sound, occasionally found in /stɹ/ sequences such as 'street', i.e., 'street' pronounced more like [ʃtɹit] rather than [stɹit]. This s-retraction has also been reported to take place in other /ɹ/-preceding positions, e.g., 'grocery' pronounced like [gɹoʃəɹi] rather than [gɹosəɹi], and exert significant inter-speaker variation, resulting in "retractors" (i.e., those who produce the [ʃ]-like sound for /s/) and "non-retractors" (i.e., those who do not). Despite the inter-speaker variation, Baker et al. (2011) showed that even non-retractors tend to produce acoustic differences for /ɹ/-preceding /s/'s. The findings from Baker et al. (2011) call for further phonetic analyses of speaker variation, and raise the question of how speaker variation can be understood.

Another pre-rhotic process, which is also post-lexical, is t-retroflection introduced in Spencer (1995: 216), originally from Nespor and Vogel (1986: 80). As illustrated in Table 1, /t/ becomes a retroflex plosive [ʈ] before /ɹ/, but only syllable-initially and within a word boundary. The examples in (a), in which all /t/'s appear as onset within a word, undergo retroflection, whereas those in (b), /t/'s as coda across words, do not.

Table 1. Pre-rhotic t-retroflection

(a)	treat	[ʈ]reat	(treat)σ
	street	s[ʈ]reet	(street)σ
	retrieve	re[ʈ]rieve	(re)σ(trieve)σ
	citrus	ci[ʈ]rus	(ci)σ(trus)σ
	destroy	des[ʈ]roy	(de)σ(stroy)σ
	nitrate	ni[ʈ]rate	(ni)σ(trate)σ
(b)	night rate	*nigh[ʈ] rate	(night)σ(rate)σ
	rat race	*ra[ʈ] race	(rat)σ(race)σ
	cut rate	*cu[ʈ] rate	(cut)σ(rate)σ
	tight rope	*tigh[ʈ] rope	(tight)σ(rope)σ

The examples in Table 1 tend to be oversimplified and thus call for empirical investigation in the following three perspectives: phonetics, phonology and morphology. First, are those /t/'s truly retroflex plosives, or are they simply retracted versions of /t/'s like /s/'s from the aforementioned s-retraction? Hamann (2003) claims that retroflex has several defining articulatory characteristics: 1) the tongue tip either in the upper (apical) or lower (sub-apical) side; 2) the posterity represented by articulatory prominence behind the alveolar region; 3) the visibility of the sublingual cavity; and 4) the retraction of the tongue. Along with various distinct articulatory properties, Hamann (2003) also claims that retroflexes inherently yield inter-speaker variation. The findings from Hamann (2003) suggest that it is necessary to examine the articulatory and gestural properties of those /t/'s in pre-rhotic contexts, which makes ultrasound imaging in this study a natural candidate. An articulatory investigation of this so-called t-retroflection can help us determine whether this pre-rhotic process is retroflection or retraction. Another phonetic issue with t-retroflection is whether retroflection only takes place in pre-rhotic voiceless coronals. This study adds the presence or absence of voicing as a potential factor in pre-rhotic retroflection. Articulatory distinctions between voiceless and voiced in English and Portuguese from Ahn (2018) provide empirical evidence that different laryngeal characteristics can result in different articulatory gestures. Comparing coronal stops with different laryngeal features, represented by voiceless and voiced coronal stops in this study, can offer new insights into this post-lexical process.

Second, given the pre-rhotic retroflection, do all /t/'s undergo retroflection regardless of syllable or word position? We can further examine whether two syllable-initial positions, word-initial or -medial, create any differences in the degree of retroflection. As various phonological and morphological effects in post-lexical processes have been discussed in previous literature (e.g., Bush 1999, 2001), it merits empirical investigation whether the degree of retroflection is affected by different positions in a word. By examining the articulatory patterns of retroflection in different contexts, this study can further our understanding of this post-lexical phonological rule.

Third, Spencer (1995) and Nespor & Vogel (1986)'s claim can be further examined by looking into /t/'s in different morphological contexts. Given all the retroflection examples in Table 1 are monomorphemic, further studies can shed light on whether /t/ retroflection takes place across a morpheme or even a word boundary, e.g., wait+ress or fast#row.

The current articulatory study reports on an investigation into phonetic variability in pre-rhotic coronal obstruents in English, focusing on /t/ and /d/ preceding /ɹ/ in various morphological contexts, plus different frequency conditions in order to examine any extra-linguistic effects in retroflection. This study poses three research questions: 1) Do voiceless and voiced pre-rhotic stops result in similar articulatory shapes? 2) Do different morphological structures, e.g., 'tree' vs. 'next room', play a role in the articulation of coronal stops before /ɹ/? 2) As in various other coarticulation phenomena, do differences in lexical frequency, e.g., 'dream' vs. 'tawdry', influence the articulation of coronal stops before /ɹ/? This study reports on the articulatory patterns of two coronal stops followed by /ɹ/ within or across a morpheme or word boundary, and also words and phrases of high and low lexical frequency.

2. Methods

2.1 Participants

Seven speakers of American English (3 females; age range from 21 to 36) at the University of Arizona were recruited for the production experiment. All speakers were speakers of Midwestern American English except for Speaker 5, and were perceived to show (some degree of) retraction, i.e., producing a [ʧ]-like sound for /tɹ/ and a [ʤ]-like sound for /dɹ/, in at least some test words.

2.2 Stimuli

Seventeen test words were chosen from the stimuli for a larger ultrasound study. Table 2 shows a list of test words that were relevant to this study. Frequency counts, presented in parentheses in Table 2, were retrieved from the Corpus of Contemporary American English (COCA, Davies 2008). As illustrated in Table 2, two morphological conditions, within- vs. across-morphemes, and two frequency conditions, high- vs. low-frequency, were considered for this study.

Table 2. Stimuli[1]

Word	Target Segment	Condition		
		Morphology	Frequency	
arbitrary	/t/	within-word	high	2,894
centric	/t/	within-word	low	61
contrast	/t/	within-word	high	26,790
Patrick	/t/	within-word	high	15,641
poultry	/t/	within-word	high	2,641
tree	/t/	within-word	high	76,768
waitress	/t/	within-word	high	4,216
fast row	/t/	across-word	low	N/A
next room	/t/	across-word	low	850
pot roast	/t/	across-word	low	268
children	/d/	within-word	high	252,830
cathedral	/d/	within-word	high	4,867
dream	/d/	within-word	high	50,390
headrest	/d/	within-word	low	364
tawdry	/d/	within-word	low	388
add rum	/d/	across-word	low	14
second row	/d/	across-word	low	9

2.3 Data collection

To examine the articulatory characteristics of pre-rhotic coronal stops, this study employed ultrasound imaging that captures tongue shapes and movements. Despite its short tradition in linguistics, ultrasound imaging has been widely used in laboratory phonology to address various phonological questions, e.g., Campbell et al. (2010), Smith et al. (2019), Yun (2006, 2008, 2012) among many. The image data for this study was collected with a SonoSite TITAN portable ultrasound unit and a C-11/7-4 11-mm broadband curved array transducer. The machine generates 30 frames per second, resulting in approximately 15-20 ultrasound tongue images per word.

[1] The frequency information of phrase stimuli (e.g., fast row) is based on the frequency of the whole phrase, not of its parts.

The ultrasound images were concurrently recorded with audio, and the visual and audio data were synchronized, creating an ultrasound tongue video as a result. Stimuli were presented to the speakers in English using a python script so that test words appear three times in a random order. While it is customary to use a head stabilization device for data collection using ultrasound imaging, this study did not use such device. Instead, this study performed post-hoc head correction on raw tongue curves after data collection.

2.4 Data procedure and analysis

The extracted and adjusted tongue contours were statistically analyzed using Smoothing Spline ANOVA (henceforth SSANOVA). Introduced in Gu (2002) and Davidson (2006), SSANOVA has been widely employed in numerous ultrasound studies to test whether two sets of tongue contours from one speaker are significantly different and generate plots of averaged tongue contours for the differences. The sets of tongue contours are considered significantly different when the confidence intervals (95%) from the sets do not overlap, equivalent to $p<.05$. Figure 1 presents an SSANOVA plot that represents the articulatory difference between /d/'s from high- vs. low-frequency words or phrases.

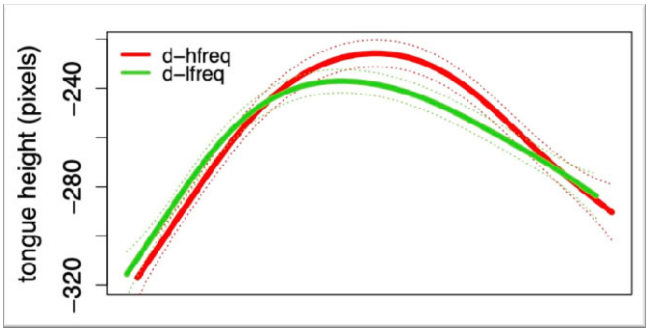

Figure 1. A sample SSANOVA plot that compares /d/'s from high-frequency and low-frequency words. Tongue tip is to the right, and shades represent 95% confidence interval. Axis values correspond to pixels. Thick lines are averaged tongue curves, and shades around them are confidence intervals of the averaged curves (95%). Dots represent the data points.

3. Results

3.1 Pre-rhotic voiceless stops

3.1.1 Within- vs. across-words

Figure 2 presents pre-rhotic /t/'s in within- and across-word conditions. Comparisons of tongue shapes in within- and across-word conditions reveal that different morphological structures have no bearing on articulatory characteristics of pre-rhotic coronals. Most speakers do not distinguish /t/'s in within- and across-word conditions. represented by a higher tongue position around the palate region.

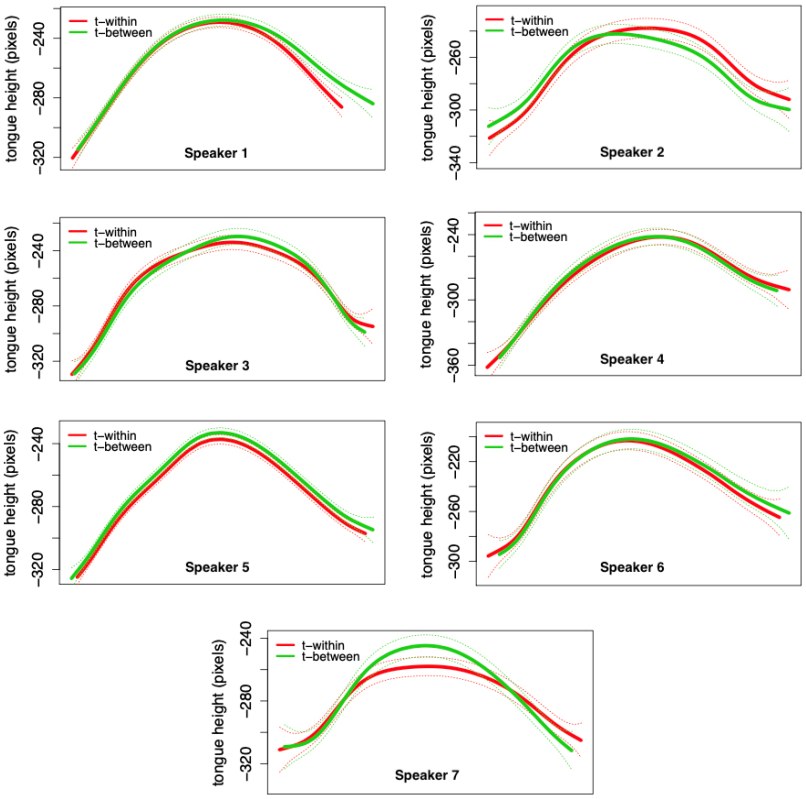

Figure 2. Pre-rhotic /t/'s in within- and across-word conditions

One of the speakers, Speaker 7, produced a slightly higher tongue dorsum in the across-word condition. While most speakers produce similar articulatory gestures for within- and across-word contexts, the gestural patterns show a clear sign of posterity, represented by a higher tongue position around the palate region. This may provide empirical evidence to support articulatory retroflection in pre-rhotic /t/'s.

3.1.2 High- vs. low-frequency

Figure 3 shows pre-rhotic /t/'s in high- and low-frequency conditions. As illustrated in comparisons of tongue curves in two morphological conditions (Figure 2), comparisons of /t/'s in two frequency contexts also suggest that gestural properties of pre-rhotic coronals are not affected by differences in lexical frequency.

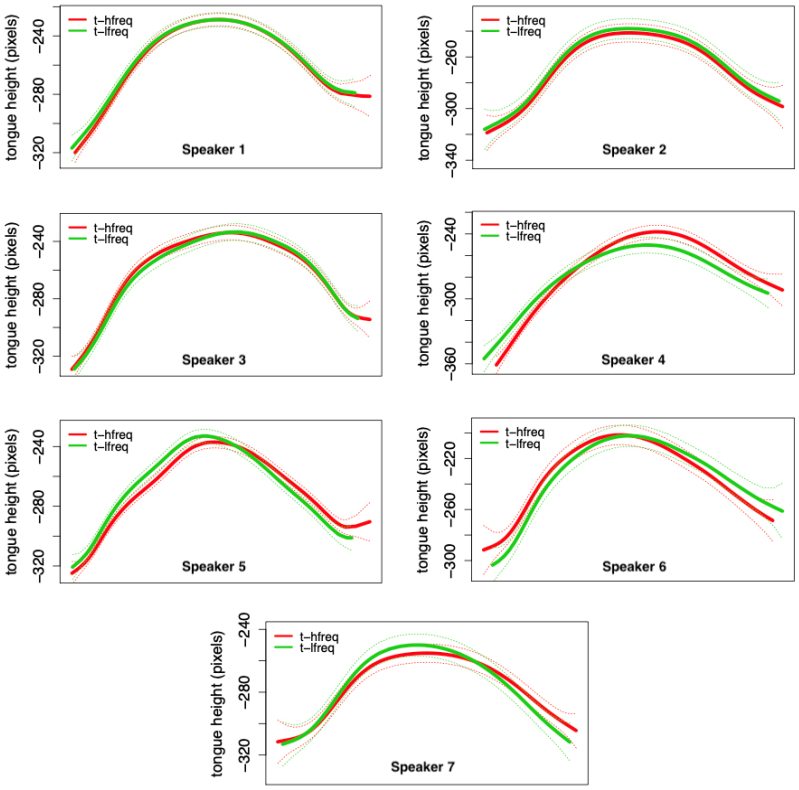

Figure 3. Pre-rhotic /t/'s in high- and low-frequency conditions

3.2 Pre-rhotic voiced stops

3.2.1 Within- vs. across-words

Figures 4 and 5 present comparisons of pre-rhotic /d/'s in two morphological conditions (Figure 4) and those in two frequency conditions (Figure 5). Note that unlike tongue curves in Figures 2 and 3, some tongue gestures in Figures 5 and 6 show that some speakers do produce significantly different tongue gestures in different morphological and frequency contexts. Comparisons of /d/'s in various morphological and frequency conditions show that some articulatory pattern seems to be shared by several speakers. For instance, a slightly greater degree of fronting in the within-word condition is found in more than one speaker's production. Note that articulatory gestures of pre-rhotic /d/'s also yield posterity represented by a higher tongue position around the palate region, along with a greater degree of fronting. When compared to the articulatory patterns of pre-rhotic /t/'s from Figure 2, tongue curves of pre-rhotic /d/'s in Figure 4 provide evidence that the voiceless and voiced coronal stops share one of the defining properties of retroflection in pre-rhotic contexts.

3.2.2 High- vs. low-frequency

Comparisons of /d/'s from high- and low-frequency words or phrases also yield articulatory patterns that are noticeably different from previously discussed patterns. Not only do quite a few speakers produce articulatory differences between two frequency conditions, but also the way speakers create differences between two conditions is not uniform at all across speakers. In addition, some speakers, Speakers 2 and 7, do seem to share similar tongue shapes in common, in that tongue gestures in the high-frequency condition tend to involve a higher tongue dorsum with a greater degree of fronting. Gestural patterns from Figures 4 and 5 suggest that pre-rhotic coronals with different laryngeal features yield similar gestural patterns, and voiced coronals are more prone to pre-rhotic processes.

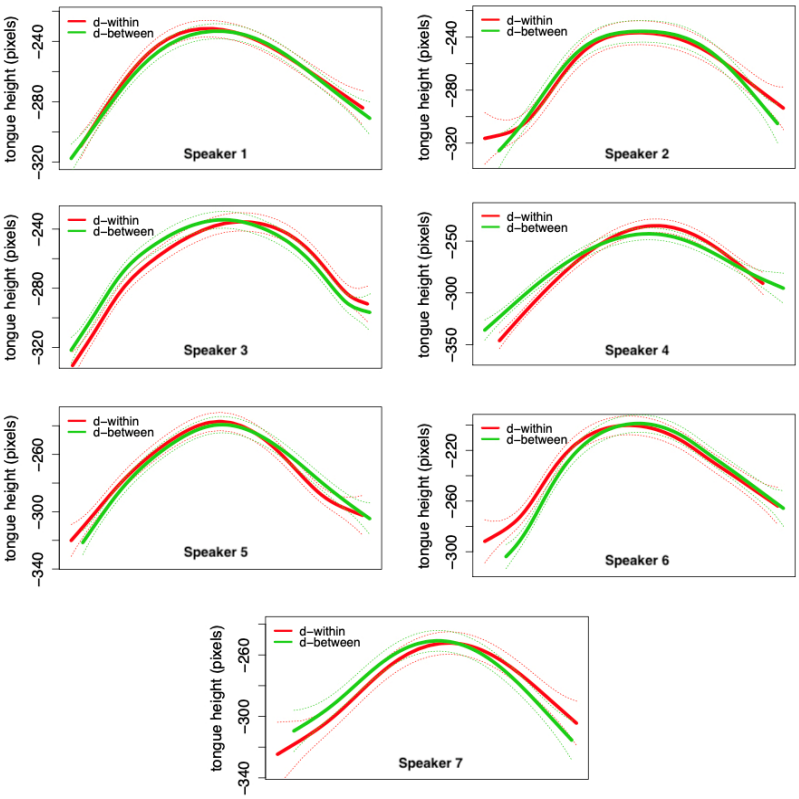

Figure 4. Pre-rhotic /d/'s in within- and across-word conditions

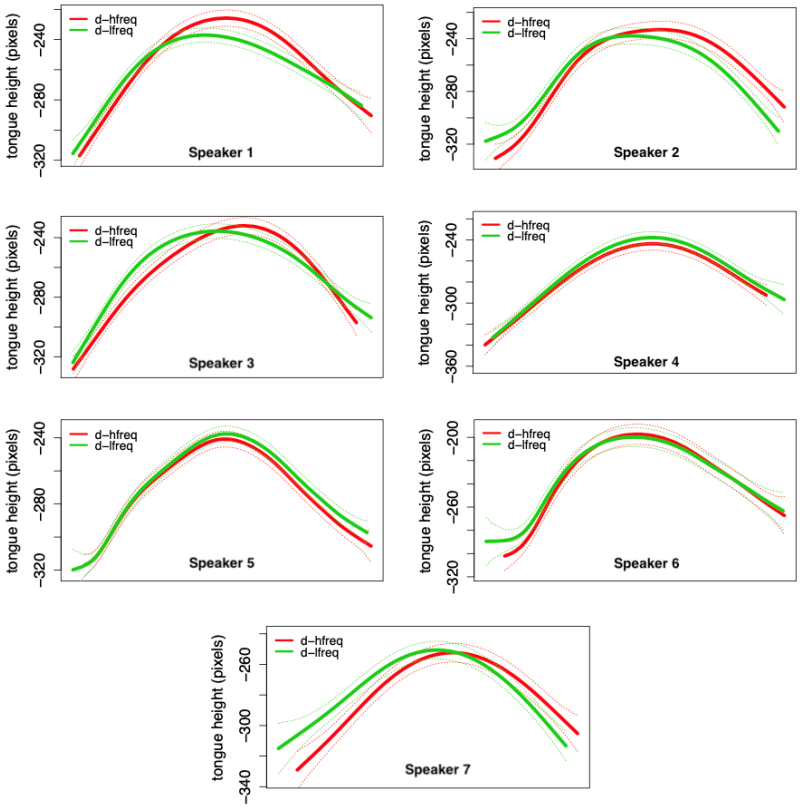

Figure 5. Pre-rhotic /d/'s in high- and low-frequency conditions

4. Discussion and conclusions

The results from this articulatory study provide empirical evidence for three aforementioned research questions from the introduction. First, pre-rhotic coronal stops with different laryngeal features both show a sign of articulatory retroflection. Second, different morphological structures, represented by within- vs. across-word contexts, do not play any significant role, at least in terms of articulation. Third, pre-rhotic coronal stops show frequency effects, albeit weakly, in voiced stops.

The gestural patterns from seven American English speakers also help us determine whether the pre-rhotic phonological process of our interest is retroflection or retraction. In an articulatory perspective, should the process be called retroflection

or retraction? Tongue curves from this study consistently show articulatory posterity, which has been previously described as one of the characteristics of retroflection. Along with posterity, some speakers, especially Speakers 2 and 7, produced a slightly greater degree of fronting, rather than retraction, in the high-frequency context, in which greater coarticulatory effects are expected. This suggests that the term retroflection is empirically supported by articulatory tongue curves to some extent.

However, the findings from this study challenge Spencer (1995)'s and Nespor & Vogel (1988)'s claim on prosodic restrictions in pre-rhotic retroflection. Different syllable positions and morphological contexts do not seem to be at play in gestural patterns of seven speakers. The articulatory patterns in this study question the role of prosodic position in pre-rhotic retroflection and call for further investigation.

Furthermore, as previously discussed in Hamann (2003), the articulatory gestures from this study show a clear sign of inter-speaker phonetic variability. While most speakers produce gestural posterity, not all speakers yield the same degree of posterity. The results from this study are in line with numerous ultrasound studies on speaker-specific variability in speech production.

The findings from this study can lead to several future studies on pre-rhotic retroflection. First, future studies can look into speakers of different dialects of English, as it has been reported that pre-rhotic retroflection may be dialectal. The current study reports on speakers of Southwestern and Midwestern dialects of American English, and future studies can verify whether similar gestural patterns are observed among speakers of different dialects.

Second, the role of different /ɹ/ types in American English (Lee 2007, Campbell et al. 2010, Smith et al. 2019) needs to be further examined in future studies. Two major articulatory variants of /ɹ/, retroflex and bunched /ɹ/, can create potential coarticulation, in a way that adjacent coronal stops are assimilated to the articulatory gestures of /ɹ/. Further articulatory analyses are necessary to examine different /ɹ/ types and their coarticulatory effects.

Third, it is also worthy of an investigation how learners of English acquire pre-rhotic retroflection as they become fluent in English. Previous empirical studies have shown non-obligatory phonological processes are produced and perceived by L2 English speakers (e.g., Yun 2012), and often evinced in loanword phonology. For instance, 'tree', as a loanword in Korean, is phonetically realized as [tɪɾi], [ʧuɾi] and [ʧjuɾi] in L1 Korean speakers' production, with the latter two variants representing /t/ retraction and affrication, and some are also reflected in Korean orthography. Such

English loans in Korean demonstrate that 1) L2 English speakers are subconsciously aware of /t/ retraction or affrication when followed by /ɹ/, and 2) non-obligatory phonological processes yield substantial variation among L2 speakers as well as L1. For this reason, articulatory behavior of retraction or affrication by L2 speakers can lead to a fuller understanding of pre-rhotic retroflection.

Overall, this study provides articulatory evidence against retroflection, but possibly for retraction or palatalization. Furthermore, the voiced coronal stop is more susceptible to pre-rhotic retroflection than its voiceless counterpart. Lastly, the articulatory patterns from this study also add weight to the growing body of literature on speaker-specific phonetic variability.

REFERENCES

AHN, SUZY. 2018. The role of tongue position in laryngeal contrasts: An ultrasound study of English and Brazilian Portuguese. *Journal of Phonetics* 71, 451-467.

BAKER, ADAM, DIANA ARCHANGELI and JEFF MIELKE. 2011. Variability in American English s-retraction suggests a solution to the actuation problem. *Language Variation and Change* 23.3, 347-374.

BUSH, NATHAN. 1999. *The Predictive Value of Transitional Probability for Word-boundary Palatalization in English.* MA thesis. The University of New Mexico.

_____. 2001. Frequency effects and word-boundary palatalization in English. In J. Bybee and P. Hopper (eds.). *Frequency and the Emergence of Linguistic Structure*, 255-280. John Benjamins Publishing.

CAMPBELL, FIONA, BRYAN GICK, IAN WILSON and ERIC VATIKIOTIS-BATESON. 2010. Spatial and temporal properties of gestures in North American English /r/. *Language and Speech* 53.1, 49-69.

DAVIDSON, LISA. 2006. Comparing tongue shapes from ultrasound imaging using smoothing spline analysis of variance. *The Journal of the Acoustical Society of America* 120.1, 407-415.

DAVIES, MARK. 2008. *Corpus of Contemporary American English.* http://www.english-corpora.org/coca/

ERNESTUS, MIRJAM, MYBETH LAHEY, FEMKE VERHEES and R. HARALD BAAYEN. 2006. Lexical frequency and voice assimilation. *The Journal of the Acoustical Society of America* 120.2, 1040-1051.

GU, CHONG. 2002. *Smoothing Spline ANOVA Models.* Springer.

HAMANN, SILKE. 2003. *The Phonetics and Phonology of Retroflexes.* LOT Press: Utrecht.

KOCHETOV, ALEXEI. 2002. *Production, Perception, and Emergent Phonotactic Patterns: A Case of Contrastive Palatalization.* Routledge.

LEE, JAE-YOUNG. 2007. Post-vocalic /r/ in English and dialect variation: A lexicon-dependent OT account. *Studies in Phonetics, Phonology and Morphology* 13.2, 325-351. The Phonology-Morphology Circle of Korea.

MYERS, JAMES and YINGSHING LI. 2009. Lexical frequency effects in Taiwan Southern Min syllable contraction. *Journal of Phonetics* 37, 212-230.

NESPOR, MARINA and IRENE VOGEL. 1986. *Prosodic Phonology.* Foris: Dordrecht.

SMITH, BRIDGET J., JEFF MIELKE, LYRA MAGLOUGHLIN and ERIC WILBANKS. 2019. Sound change and coarticulatory variability involving English /ɹ/. *Glossa: A Journal of General Linguistics* 4.1, 63.

SPENCER, ANDREW. 1995. *Phonology: Theory and Description.* Wiley-Blackwell.

YUN, GWANHI. 2006. *The Interaction Between Palatalization and Coarticulation in Korean and English.* PhD Dissertation. The University of Arizona.

_____. 2008. An articulatory study of vowel assimilation and V-to-V coarticulation. *Studies in Phonetics, Phonology and Morphology* 14.1, 121-141. The Phonology-Morphology Circle of Korea.

_____. 2012. Lexical and phonological effects on phonological variation in L2 English palatalization. *Studies in Phonetics, Phonology and Morphology* 18.2, 297-320. The Phonology-Morphology Circle of Korea.

ZSIGA, ELIZABETH, C. 1993. *Features, Gestures, and Temporal Aspects of Phonological Organization*. PhD Dissertation. Yale University.

_____. 1995. An acoustic and electropalatographic study of lexical and postlexical palatalization in American English. In B. Connell and A. Arvaniti, *Phonology and Phonetic Evidence: Papers in Laboratory Phonology IV*, 282-302. Cambridge University Press.

_____. 2000. Comparing tongue shapes from ultrasound imaging using smoothing spline analysis of variance. *The Journal of the Acoustical Society of America* 120.1, 407-415.

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Received: November 22, 2020
Revised: December 18, 2020
Accepted: December 24, 2020