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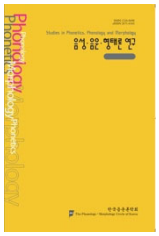

Speaker-specific Variability in Pre-/ɹ/ Retroflexion in L2 English*

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Abstract

While lexicalized phonological processes tend to be rule-governed and yield categorical patterns, post-lexical processes result in a great deal of phonetic variability across speakers. Of our special interest is whether highly individualized patterns are acquired by L2 learners and how they are articulatorily manifested in L2 speech. Using ultrasound imaging of five Korean learners of English, the present study investigates the articulation of coronal stops followed by /ɹ/, known as /ɹ/-induced retroflexion, and examines the inter-speaker variation among L2 learners. Tongue contours produced by L2 speakers confirm highly individualized patterns across speakers, along with different degrees of retraction within and across morphemes and words. The gestural patterns offer new insights into covert articulatory patterns that emerge from L2 speakers, and add to the growing evidence of inter-speaker variation in L2 speech as well as in L1.

Keywords

variability, retroflexion, retraction, articulation, L2 English

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1. Introduction

It is widely acknowledged that English coronal obstruents that precede /ɹ/ undergo various phonological processes, exemplified by /s/ retraction (Baker et al. 2011) as in *street* and /t/ retroflexion, as in *tree* (Spencer 1995). These post-lexical processes exhibit highly idiosyncratic patterns among native speakers of the language, partly because they do not exist as obligatory phonological rules. While both obligatory and non-obligatory phonological rules serve as the language input that learners are exposed to, this study reports ultrasound-based articulatory findings on how L2 learners of English, represented by young Korean learners of English, acquire and produce pre-/ɹ/ coronal retroflexion, one of the non-obligatory phonological rules in English.

1.1 Obligatory and non-obligatory phonological processes

In many languages, phonological processes can appear as either obligatory or non-obligatory phonological rules. For instance, /t/ in *righteous* undergoes overt, mandatory palatalization, involving the [t]-to-[tʃ] change, while /t/ in *might you* may or may not lead to any overt palatalization of /t/. Post-lexical processes such as (lack of) palatalization in *might you* serve as a challenge to language learners, and also call for an investigation on how language learners acquire and apply non-obligatory phonological rules.

1.2 Speaker-specific variability in L1 and L2 speech

What makes it even more difficult for language learners to acquire non-obligatory phonological rules is speaker-specific variability produced by both L1 and L2 speakers. Recent laboratory studies have shown a clear sign of gradience, represented by language-specific and speaker-specific variability (Baker et al. 2011, Derrick and Gick 2011, Schertz et al. 2015, Mielke et al. 2016, Smith et al. 2019, Sung 2020 among many), which are often not consistent nor systematic.

Baker et al. (2011), based on their ultrasound-based results on s-retraction, reported on “retractors” and “non-retractors”. Some speakers (“retractors”) produce retracted /s/, i.e., [ʃ], in words such as [s]*treet* and *gro*[c]*ery*, while others (“non-retractors”) simply do not do so, albeit some context-dependent variation. Derrick

and Gick (2011), also based on the ultrasound-based analysis, showed individual variation in production of flaps and taps which were not governed by phonological contexts. Schertz et al. (2015) examined native Korean speakers' production and perception of stop categories in their L1 (Korean) and L2 (English), and revealed categorical variation in cue-weighting strategies, in which some speakers primarily use VOT, some rely on f0, and some utilize both cues. Mielke et al. (2016) and Smith et al. (2019) reported on similar categorical variation in /ɹ/ gestures in American English, in which some produce only retroflex /ɹ/, some only bunched /ɹ/, and some both gestures, allowing idiosyncratic patterns. Sung (2020) took a closer look at pre-rhotic coronal obsruents produced by native speakers of American English, and showed that native speakers of English produce non-systematic, various degrees of palatalization-like retraction.

While the aforementioned previous research identified and documented inter-speaker variation in speech production and perception, little is known about individual variation among L2 speakers and linguistic or extra-linguistic forces behind such variation. Among numerous phonological processes that lead to individual variation, following up on Sung (2020), the present study focuses on /ɹ/-induced retroflexion in coronal obstruents in English produced by L2 learners.

1.3 /ɹ/-induced retroflexion in English

/ɹ/-induced retroflexion in coronal obstruents in English has been spotlighted in several previous studies. Examples of such retroflexion are illustrated in Table 1. Spencer's (1995) description of the process indicates that /t/ becomes a retroflex plosive [ʈ] when followed by /ɹ/, but only within a word and also a syllable (σ). Retroflexion does not take place across a word boundary.

Table 1. /ɹ/-induced retroflexion in Spencer (1995: 216)

treat	[ʈ]reat	(treat)σ
street	s[ʈ]reet	(street)σ
retrieve	re[ʈ]rieve	(re)σ(trieve)σ
destroy	des[ʈ]roy	(de)σ(stroy)σ
night rate	*nigh[ʈ] rate	(night)σ(rate)σ
rat race	*ra[ʈ] race	(rat)σ(race)σ

cut rate	*cu[t] rate	(cut)σ(rate)σ
tight rope	*tigh[t] rope	(tight)σ(rope)σ

The data in Table 1 and Spencer's (1995) description of the process is oversimplified and thus call for an empirical investigation in two perspectives. First, is the resulted obstruent truly a retroflex? Several previous studies including Ladefoged and Bhaskararao (1983) and Hamann (2002, 2003) suggest that retroflexes are produced in a continuum of places of articulation and involve multiple distinct gestures. Hamann (2013) identified four major articulatory characteristics of retroflexes: 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; 4) the retraction of the tongue. Hamann's (2002, 2003) description suggests that retroflexion and retraction share quite a few gestural characteristics in common, and this study examines in what ways L2 speakers' production of pre-/ɹ/ coronal stops shows retroflexion or retraction. Second, the presence or absence of /t/-retroflexion needs to be empirically examined. Based on ultrasound-based articulatory analyses, various degrees of retroflexion are expected to be found among speakers of /t/-retroflexion. Furthermore, an articulatory examination of /t/-retroflexion needs to be done in more varied phonological contexts.

Along with the aforementioned issues, of our special interest is how these speaker-specific patterns are learned by L2 speakers and articulatorily manifested in L2 speech. Non-obligatory phonological processes are produced and perceived by L2 English speakers (Yun 2012), and often evinced in loanword phonology. For instance, *tree*, as a loanword in Korean, is phonologically realized as /tʰɨri/ (/트리/), /tɕʰjuɾi/ (/츄리/), and /tɕʰuɾi/ (/추리/) in L1 Korean speakers' production, with the latter two variants representing /t/ retraction and affrication, and it is noteworthy that these variants are also reflected in Korean orthography.

Figure 1. Google search results on the Korean loan /tʰɨri/ (/트리/) variants

The existence of variants in Korean loans suggests that L2 English speakers are subconsciously aware of /t/ retraction or affrication after /ɹ/, and non-obligatory phonological processes create substantial variation among L2 speakers as well as L1 speakers. Using ultrasound imaging, this study investigates the articulation of coronal stops followed by /ɹ/ (henceforth pre-/ɹ/ stops) produced by young Korean learners of English and examines the inter-speaker variation in L2 English.

2. Methods

2.1 Participants

Ten L1 Korean speakers in their who have learned English as their L2, participated in the production experiment, and 5 out of 10 speakers (three females) were analyzed for the present study. All five participants were intermediate learners of English, and spent less than one year in any English-speaking country.

2.2 Stimuli

Pre-/ɹ/ stops in moderately frequent words and phrases in various phonological and morphological contexts were chosen and produced by speakers, as illustrated in Table 2. Previous studies on /t/-retroflexion reported articulatory changes in within-morpheme conditions, not across morpheme or word boundaries. For this reason, *tree* and *street* are expected to yield greater degree of gestural retroflexion, compared to *actress* and *night reading*.

Table 2. Examples of stimuli and phonological contexts

Word/Phrase	Context
tree	word-initial, monomorphemic
street	s-following, monomorphemic
actress	word-medial, across morphemes
night reading	word-final, across words

2.3 Procedure

The present study employs ultrasound imaging to examine the articulatory patterns of /t/ retroflexion. The merit of ultrasound imaging in L2 research has been known for its portability and non-invasiveness through empirical studies over the past decade (Gick et al. 2008, Byun et al. 2014, Wilson and Gick 2014 among many), and makes it a natural candidate to conduct this study.

Tongue images were collected using the Articulate Assistant Advanced (AAA) software (Articulate Instruments Ltd. 2012) and the Micro system with the stabilization headset (Articulate Instruments Ltd. 2008), which prevents participants from moving their head during the experiment. All participants were instructed to wear the stabilization headset that fixes their chin to the 5 to 10 MHz convex-curved transducer, sit comfortably in front of a laptop monitor and read the words on the monitor at a normal speed.

Image frames corresponding to the test words were identified and extracted. For frame identification, this study used the aforementioned Articulate Assistant Advanced (AAA) software which enables us to view ultrasound tongue images and their corresponding acoustic signals simultaneously. Image frames of target segments were identified based on the corresponding acoustic signals.

2.4 Analysis

The extracted tongue contours were statistically analyzed using Smoothing Spline ANOVA (henceforth SSANOVA; Gu 2002 and Davidson 2006) and the ggplot2 R package (Wickham 2016). The x-axis in Figure 2 represents position along the tongue, where the leftmost endpoint is the tongue root and the rightmost endpoint is the tongue tip. The y-axis represents raw tongue height in mm. As shown in Figure 2, tongue positions of pre-/ɹ/ /t/'s within and across words, represented by pink and green curves respectively, do not overlap in the tongue dorsum. This suggests that there is a significant difference in /t/'s in three phonological contexts. The present or absence of significant differences in tongue curves will be used to determine whether speakers make articulatory contrast between different conditions.

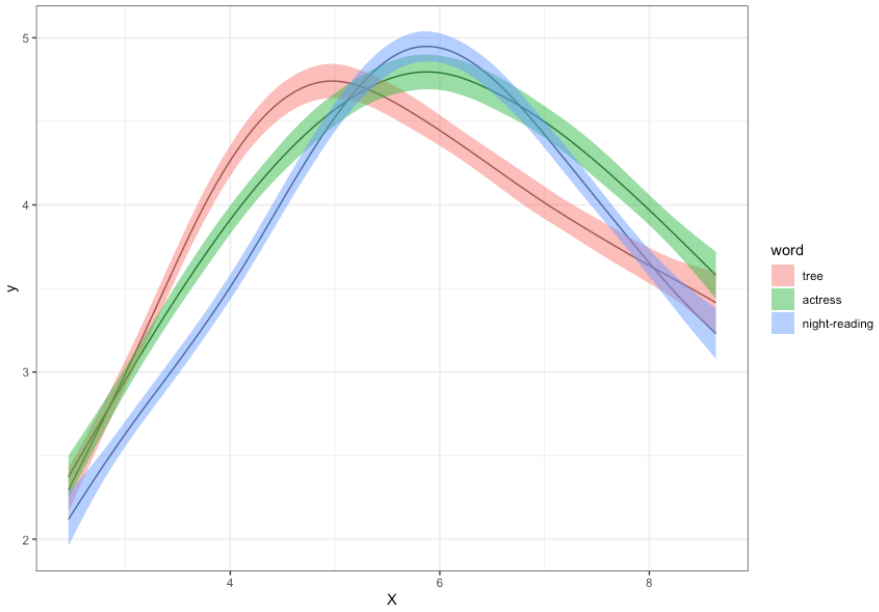


Figure 2. An SSANOVA analysis of tongue contours. Tongue tip is to the right, and shades represent 95% confidence intervals. Axis values correspond to mm. Solid lines are averaged tongue curves, and shades around them are confidence intervals of the averaged curves. Where fewer data points are available, the shaded area is larger.

3. Results

Table 3 summarizes the gestural patterns from six speakers in this study. Inter-speaker variation will be further discussed along with the following SSANOVA analyses.

Table 3. Summary of the Gestural Patterns

Conditions	Gestural Patterns
Word-initial vs. s-following (*tree* vs. *street*)	higher tongue tip for s-following
Word-initial vs. -medial vs. -final (*tree vs. actress* vs. *night reading*)	higher tongue tip and back for word-medial and -final

Within- vs. across-morpheme (*tree vs. actress*)	higher tongue tip and/or back for across-morpheme
Within vs. across-word (*tree* vs. *night reading)*	higher tongue tip and/or back for across-word

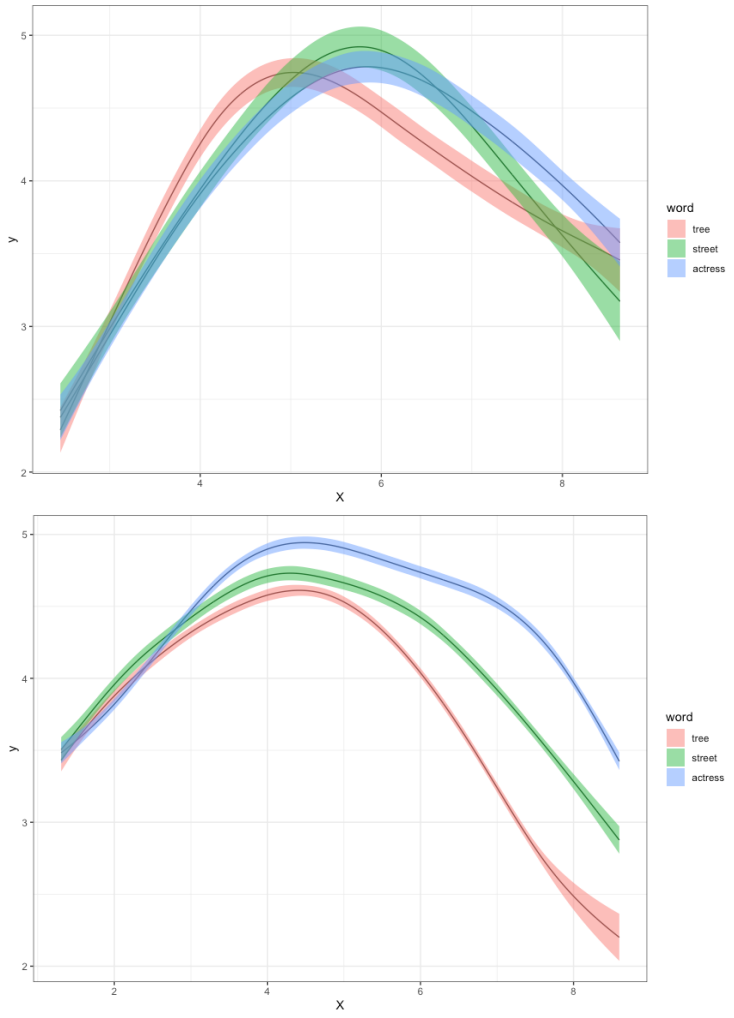
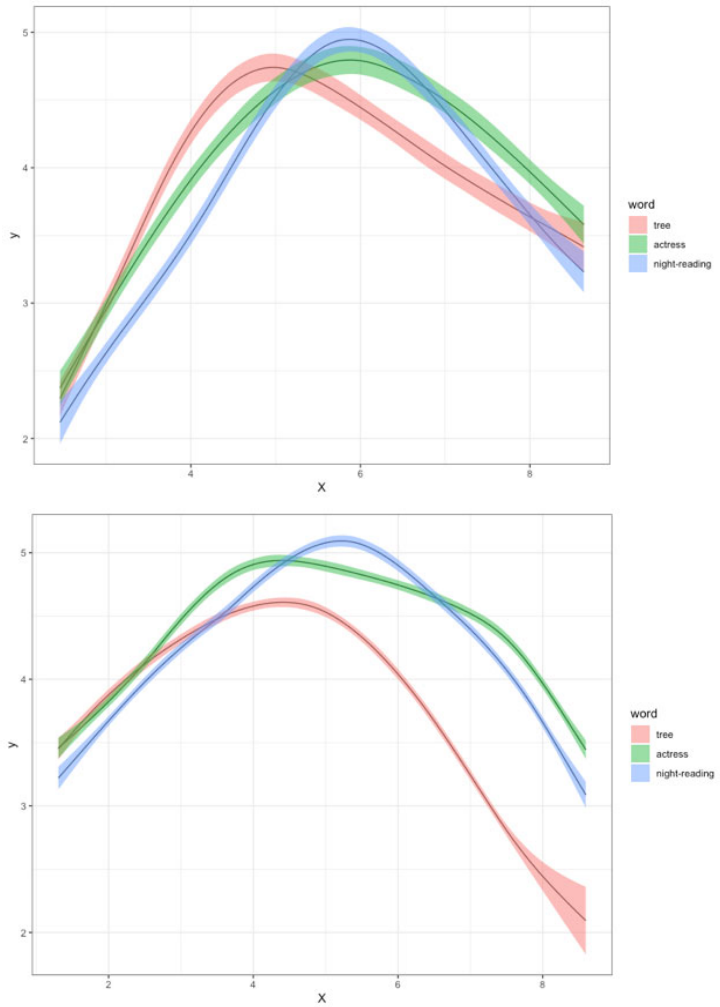


Figure 3. An SSANOVA analysis of *tree* (word-initial, within a word), *street* (word-medial, within a word), and *actress* (word-medial, across a morpheme boundary) from two speakers.

Figures 3 and 4 show comparisons of pre-/ɹ/ /t/'s in three within-word conditions and one across-word condition. Comparisons of three within-word conditions (Figure 3) show that Korean learners of English make articulatory contrast for subtle phonological and morphological differences, represented by retraction (tongue dorsum made backer) and palatalization (tongue blade made higher and closer to the palate). One speaker (upper graph of Figure 3) shows a clear sign of retraction for *tree* compared to other two within-word contexts, and the other speaker (lower graph of Figure 3) makes a 3-way articulatory distinction in which *actress* shows the greatest degree of palatalization, *street* next, and *tree* yielding no overt palatalization.



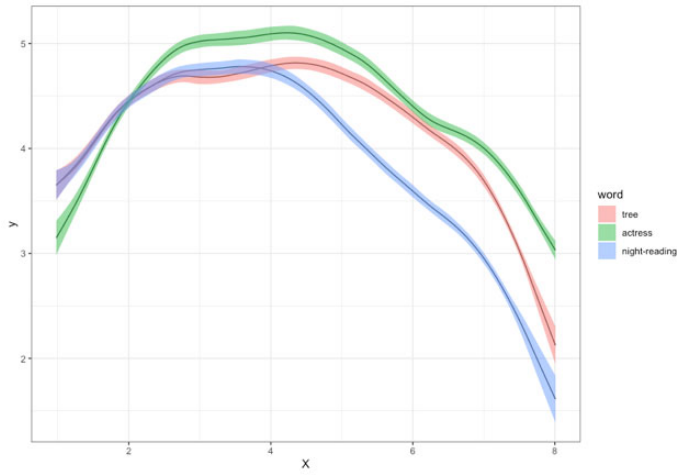


Figure 4. An SSANOVA analysis of *tree* (word-initial, within a word), *actress* (word-medial, within a word), and *night reading* (word-final, across a word boundary) from three speakers.

Figure 4 illustrates comparisons of two within-word conditions (*tree* and *actress*) and one across-word condition (*night reading*). All three speakers exhibit a clear sign of 3-way contrast of pre-/ɹ/ stops in monomorphemic (*tree*), dimorphemic (*actress*), and across-word contexts (*night reading*). Along with the articulatory contrast, the way speakers differentiate contexts is not uniform across speakers. One speaker (the top graph) makes the articulatory distinction mostly in the tongue dorsum, in which *tree* shows the most retracted tongue dorsum. Another speaker (the middle graph) distinguishes three contexts mostly in the tongue tip and blade regions, in which *tree* is farthest from the palate and *night reading* closest to the palate. Another speaker (the bottom graph) shows an almost 2-way distinction between within-word and across-word conditions, in which *night reading* is farther from the palate compared to two within-word conditions.

4. Discussion and Conclusions

Preliminary analyses of pre-/ɹ/ stops in this study show that L2 speakers produce various degrees of retraction and palatalization, in which retraction is represented by higher tongue dorsum and palatalization by higher tongue tip. Word-initial pre-/ɹ/

stops show retraction when compared to non-initial ones, and across-morpheme or -word pre-/ɹ/ stops tend to show palatalization when compared to within-morpheme ones, along with individualized patterns. When a speaker produces pre-/ɹ/ stops, they tend to differentiate /t/s in within-word, e.g., *tree*, *street,* and across-word, e.g., *night reading,* contexts, and the way the contrast is made is not uniform across speakers, as previously found in L1 English speakers. As illustrated in the aforementioned figures, some speakers produce more retraction within words than across words, while others show the opposite trend. Moreover, similar tongue shapes are made among monomorphemic words within each speaker, showing L2 speakers' awareness of morphological boundaries.

Going back to the previously introduced issues, do L2 speakers' pre-/ɹ/ stops show retroflexion? Hamann's (2002, 2003) criteria of retroflexion seem to explain the articulatory gestures produced by Korean learners of English. The articulatory distinction made by speakers shows a sign of articulatory prominence in the tongue back region, and retraction, which is in line with previous findings on retroflex production in other languages (e.g., Kochetov et al. 2014). What is also noteworthy is that none of the articulatory gestures involved the "curled-in" gesture (Bhat 1973, 1974) that used to be expected for a retroflex. It calls for further investigation whether such articulatory characteristics are specific to English or Korean learners of English. In addition, the gestural patterns produced by L2 speakers provide complementary documentation on /ɹ/-induced retroflexion in English.

Moreover, our findings on L2 speakers producing (lack of) pre-/ɹ/ retroflexion in various phonological contexts suggest that there is substantial and noticeable variation among L2 speakers. Whether or not they are aware of pre-/ɹ/ retroflexion, Korean learners of English are aware of subtle differences in phonological and morphological contexts, represented by distinct articulatory gestures in various conditions.

Given that the articulatory data in this study come from L2 speakers, is the individual variation herein reported due to speakers' mispronunciation of target consonants, or L1 transfer from variants in Korean loanwords, as shown in /tʰɨɾi/ (/트리/), /tɕʰjuɾi/ (/츄리/), and /tɕʰuɾi/ (/추리/) earlier? All test words analyzed in this study are highly frequent words which can hardly lead to mispronunciation, and no clear sign of mispronunciation was found in the analyzed data. Loanword variation for *tree* might have influenced the gestural patterns for the word, but it is not likely

that it affected the individual variation across different words in various phonological and morphological conditions.

Future articulatory analyses can explore other linguistic factors that might have caused individual variation from this study. Given that /t/-retroflexion is induced by the immediately following /ɹ/, it is worth investigating whether the gestural patterns of /ɹ/ (e.g., retroflex vs. bunched /ɹ/, as noted in Byun et al. 2014 and Mielke et al. 2016) result in meaningful coarticulation that leads to variation of pre-/ɹ/ stops. An articulatory examination of /ɹ/ produced by L2 speakers will also provide complementary documentation of /ɹ/ variation reported in studies with L1 speakers.

Overall, the gestural patterns from this study offer new insights into covert articulatory patterns that emerge from L2 speakers, and add to the growing evidence of inter-speaker variation in L2 speech as well as in L1. Future research with speakers of different proficiency levels and stimuli with various extralinguistic factors will further our understanding of inter-speaker variability produced by language learners.

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