The Articulation of Lexical and Post-lexical palatalization in Korean

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Abstract

Palatalization in Korean is of two types - lexical palatalization governed by language-specific phonological rules, and post-lexical palatalization that appears to be purely phonetic. While lexical palatalization only occurs when a morpheme boundary intervenes between a target consonant and a palatalization trigger, post-lexical palatalization occurs irrespective of the presence of a morpheme boundary. This study investigates whether these two types of palatalization and different morphological structures of words manifest as distinct tongue gestures using ultrasound imaging of 4 native speakers of Korean. Comparison of the ultrasound tongue contours shows that the gestural distinction between lexical and post-lexical palatalization may not be the same across individual speakers. Furthermore, the effects of morpheme boundaries are not uniform across different coronal consonants and speakers in terms of tongue gestures. The findings from this study provide further empirical evidence for the role of morphological structures in coarticulation, and are in line with mounting evidence for speaker-specific variability in speech production.

Index Terms: speech production, ultrasound, palatalization, Korean

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1. Introduction

This study investigates the articulatory patterns of lexical and post-lexical palatalization in Korean using ultrasound imaging. More specifically, the study examines how two types of palatalization in Korean and different morphological structures of words are shown in tongue gestures.

Palatalization refers to a type of coarticulation in which the place of articulation of some sound is closer to the palate than otherwise expected, triggered by adjacent palatal segments. Palatalization is observed in many languages [1], and is one of the well documented phenomena in the literature in terms of its relation to various higher-level linguistic structures in individual languages such as their phonological and morphological characteristics.

It has been widely acknowledged that some palatalization processes are governed by language-specific phonological rules ("lexical" palatalization), and others appear as a language-universal phonetic process ("post-lexical" palatalization). In Korean, lexical palatalization occurs only when there is a morpheme boundary between an alveolar noncontinuant obstruent and a palatalization trigger, which is either a front vowel [i] or a palatal glide [j] [2, 3, 4]. Table 1 shows three Korean words that exemplify lexical and post-lexical palatalization. The first two Korean words, /mat+i/ 'the eldest' and /mati/ 'joint, node', show very similar underlying representation in Korean. However, only /mat+i/ 'the eldest' undergoes lexical palatalization because of its morphological structure showing a compound boundary (+) between /mat/ 'the eldest' and /i/ (nominalizer). On the other hand, /mati/ 'joint, node' is a monomorphemic word, only resulting in post-lexical palatalization. All other consonants which are not noncontinuant obstruents exhibit post-lexical palatalization, which occurs without regard to the presence of a morpheme boundary, as illustrated in the /s/ and /n/ examples.

Table 1: *Lexical and post-lexical palatalization in Korean.*

type	example	effect
lexical	/mat+i/ 'the eldest'	/t/ → [tʃ]
post-lexical	/mati/ 'joint, node'	/t/ → [tʲ]
post-lexical	/kasi/ 'thorn'	/s/ → [ʃ]
post-lexical	/koni/ 'swan'	/n/ → [nʲ]

The articulatory patterns of palatalization in Korean have been reported in various experimental studies. Different phonological and morphological conditions affect the degree of gestural overlap [5, 6] and coarticulation of adjacent vowels [7, 8], and the extent of palatalization represented by tongue contours [9]. Furthermore, a pilot ultrasound study on post-lexical /n/ palatalization [9] claims that the gestural patterns of palatalization are not necessarily shared by native speakers of the language, resulting in a large degree of inter-speaker variability in their speech production. Following the previous studies, this study further explores the role of morphological structures and speaker-specific variability in coarticulatory processes such as palatalization.

2. Methods

2.1. Participants

4 native speakers of Korean who currently live in Tucson, Arizona were recruited for the production experiment. The participants have been living in the U.S. for 5 to 10 years, but they all speak Korean at home in Tucson, and are involved in Korean speaking communities on a regular basis. All the participants speak English as their second language. Table 2 presents the participants' demographic information.

Table 2: *Demographic information of participants.*

speaker #	gender	age	L1 dialect
S1	female	29	Busan
S2	female	31	Seoul
S3	female	28	Ulsan
S4	female	30	Busan

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2.2. Stimuli

38 Korean words were used in the production experiment, comprised of 21 test words and 17 fillers. Table 3 shows the subset of words used in the experiment based on their phonological and morphological contexts. For comparison with lexical palatalization which only affects coronal stops, only post-lexical palatalization of coronal consonants was considered in this study. The stimuli were randomly presented three times in Korean orthography, which resulted in 114 tokens to analyze for each speaker.

Table 3: *Examples of the stimuli.*

segment	type	word	gloss
/t/	lexical	/mat+i/	'the eldest'
/t/	post-lexical	/puti/	'please'
/t^h/	lexical	/kat^h+i/	'together'
/t^h/	post-lexical	/pu+t^hi/	'rich attitude'
/s/	post-lexical	/kasi/	'thorn'
/s/	post-lexical	/mos#i/	'nail + nominative'
/n/	post-lexical	/koni/	'swan'
/n/	post-lexical	/mun#i/	'door + nominative'

2.3. Procedure

All the experiments were conducted in the Arizona Phonological Imaging Lab at the University of Arizona. Participants were instructed to read out the words presented on a computer screen at a normal speaking rate. All the instructions were given in Korean. During the experiment session, with the ultrasound transducer held in position, speakers were allowed to move their heads freely without any head stabilization device. After the data was collected, tongue contours were adjusted based on the palate contour obtained at the beginning of each experiment session.

2.4. Analysis

Image frames corresponding to the palate contours and the test words were identified and extracted based on the corresponding acoustic signals. Once the image frames of interest were identified, the tongue curves shown in the frames were manually labelled. The data points from the labelled tongue contours were statistically analyzed using Smoothing Spline ANOVA (henceforth SSANOVA) [10, 11] to test whether two sets of tongue contours from one speaker are significantly different. The sets of tongue contours are considered to be different when the confidence intervals (95%) for the two sets do not overlap, equivalent to $p<.05$.

Figure 1 shows an example of SSANOVA analysis from the Korean data in this study, which presents comparison of two averaged tongue curves, word-medial /n/'s in monomorphemic and bimorphemic palatalization environments. The x-axis in Figure 1 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 pixels. As shown in Figure 1, confidence intervals for tongue positions of two palatalized /n/'s do not overlap in the tongue front nor in the back region. This suggests that there is significant difference in word-medial /n/s in two conditions.

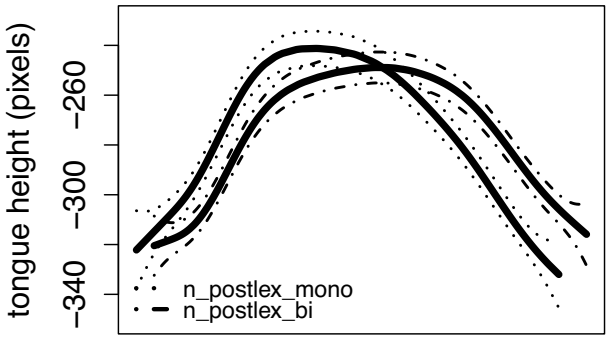

Figure 1: *An example of SSANOVA plot of tongue contours for word-medial /n/ in two palatalization environments. Thick lines are averaged tongue curves, and dotted lines are confidence intervals of the averaged curves (95%).*

3. Results

3.1. Plain vs. palatalized

Figure 2 and 3 present comparisons of plain vs. palatalized /t/ and /t^h/, respectively. Palate contours extracted from individual speakers are provided as a reference. Due to the poor quality of images, only the data from speakers 2 and 4 were analyzed for plain vs. palatalized /t/ and /t^h/. As illustrated in Figure 2 and 3, the difference between plain and palatalized consonants is manifested as tongue gestures in 3 out of 4 comparisons. While the speakers make significantly different tongue curves for different conditions, they do not share the same gestural patterns here. For instance, speaker 2 makes the higher tongue curve in the palatalized environment than in the plain one, whereas speaker 4 does not show such trend. The patterns observed here support inter-speaker variability in coarticulatory processes.

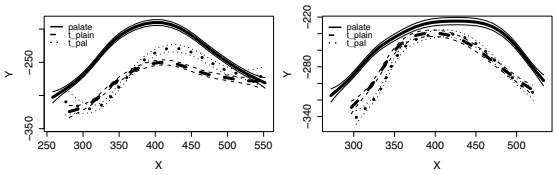

Figure 2: *SSANOVA plots of tongue contours from speaker 2 (left) and 4 (right): plain vs. palatalized /t/*

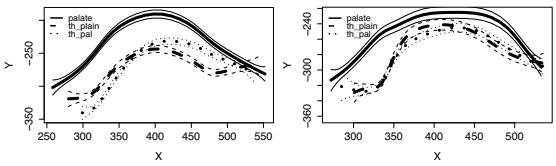

Figure 3: *SSANOVA plots of tongue contours from speaker 2 (left) and 4 (right): plain vs. palatalized /t^h/*

Figure 4 and 5 show comparisons of plain vs. palatalized /s/s and /n/s, respectively. While all 4 speakers make distinct tongue gestures for plain vs. palatalized consonants, it is clear that the gestural differences between plain and palatalized consonants are more noticeable in post-lexical /s/ and /n/ palatalization. In Figure 4, all 4 speakers show a higher tongue curve in the tongue dorsum in the palatalization environment.

As seen in those from lexical palatalization, the results from post-lexical palatalization yield individualized patterns. In Figure 5, speaker 2 shows a higher tongue curve in the front region of the tongue, while all other speakers show the opposite pattern. In addition, while speaker 2 hardly makes any gestural distinction in the back region, all other speakers show a clear sign of backing in the palatalization environment.

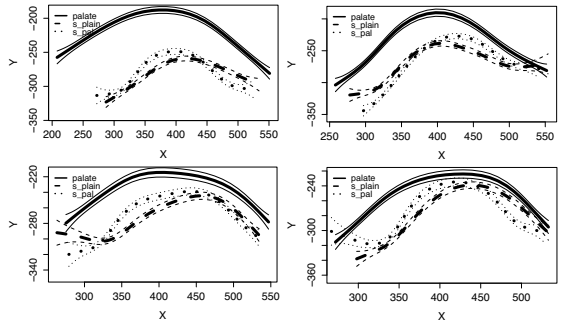

Figure 4: *SSANOVA plots of tongue contours from all speakers - speaker 1 (top left), 2 (top right), 3 (bottom left), and 4 (bottom right): plain vs. palatalized /s/*

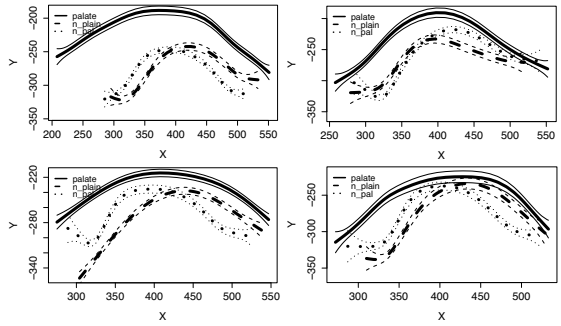

Figure 5: *SSANOVA plots of tongue contours from all speakers - speaker 1 (top left), 2 (top right), 3 (bottom left), and 4 (bottom right): plain vs. palatalized /n/*

Overall, it is clear that the distinction between plain and palatalized consonants emerges as different tongue gestures, and the way speakers distinguish them is not uniform across types of consonants and individual speakers.

3.2. Lexical vs. post-lexical palatalization

Figure 6 and 7 present comparisons of lexical and post-lexical /t/ and /t^{h}/ palatalization respectively. Due to the aforementioned problem in the previous section, only the data from two speakers are shown in Figure 6 and 7.

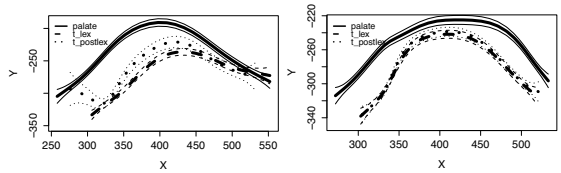

Figure 6: *SSANOVA plots for lexical vs. post-lexical /t/ palatalization - speakers 2 (left) and 4 (right).*

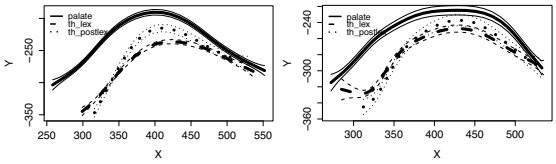

Figure 7: *SSANOVA plots for lexical vs. post-lexical /t^{h}/ palatalization - speakers 2 (left) and 4 (right).*

What is noticeable in Figure 6 and 7 is that the distinction between lexical and post-lexical palatalization does not always show up as different tongue gestures. Figure 6 shows that the gestural difference between lexical and post-lexical /t/ palatalization is not guaranteed even though the outcome from two types of palatalization is considered phonetically different ([ʧ] by lexical palatalization and [t^{j}] by post-lexical palatalization). For instance, speaker 4 does not make any gestural distinction between lexical and post-lexical palatalization.

As illustrated in Figure 7, the palatalized /t^{h}/s by lexical palatalization are characterized by a higher tongue curve in the front region of the tongue, showing a greater degree of palatalization. Given that two palatalization processes result in phonetically different sounds, [ʧ^{h}] for lexical palatalization and [t^{hj}] for post-lexical palatalization, the gestural differences observed here are not too surprising.

In sum, as shown in plain vs. palatalized comparison, the results from lexical vs. post-lexical comparison evidence the articulatory differences in palatalized consonants from two different palatalization processes. However, the articulatory differences do not necessarily show up in every speaker's production.

3.3. Morphological effects in palatalization

Figure 8 and 9 show the gestural patterns of post-lexical palatalization for /s/ and /n/ respectively. While the articulatory patterns of post-lexical /s/ palatalization do not distinguish within- and across-morpheme palatalization (Figure 8), those of post-lexical /n/ palatalization yield significant gestural differences between within- and across-morpheme palatalization, showing a clear sign of boundary effects (Figure 9). The findings on post-lexical /n/ palatalization also confirm [9]'s claim on boundary effects in post-lexical /n/ palatalization.

As seen in the above-discussed results, the gestural characteristics of post-lexical palatalization also exhibit individualized patterns. In Figure 9, speaker 2 does not show any gestural difference between two morphologically different conditions, while all other speakers show a significantly higher tongue contour in the within-morpheme (monomorphemic) condition, which can be understood as a greater degree of palatalization in the within-morpheme condition. The fact that the majority of speakers shows a greater degree of palatalization within morphemes further supports the language-universal tendency for greater coarticulation in tautomorphemic environments.

Overall, the presence of a morpheme boundary plays a role in the gestural patterns of some post-lexical palatalization. Along with the previously reported findings in this study, the results on the role of a morpheme boundary also support speaker-specific variability in speech production. The findings from the current study are summarized in Figure 10.

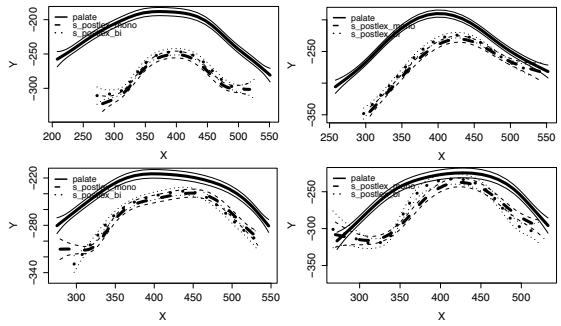

Figure 8: *SSANOVA plots for within- (mono) vs. across-morpheme (bi) post-lexical /s/ palatalization - speaker 1 (top left), 2 (top right), 3 (bottom left), and 4 (bottom right).*

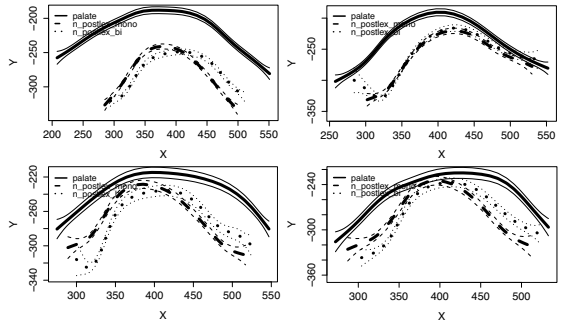

Figure 9: *SSANOVA plots for within- (mono) vs. across-morpheme (bi) post-lexical /n/ palatalization - speaker 1 (top left), 2 (top right), 3 (bottom left), and 4 (bottom right).*

4. Discussion and Conclusion

While the work here only reports the data from the gestural peaks (midpoints) of segments, the articulatory patterns of palatalization observed in this study show that the difference between lexical and post-lexical palatalization (i.e., lexical vs. post-lexical /t/ & /t^h/ palatalization) is sometimes manifested by distinct tongue gestures, but not always. Moreover, different morphological structures (i.e., within- vs. across-morpheme palatalization) play a significant role in some post-lexical palatalization.

The preliminary results from 4 Korean speakers reported here show a clear sign of palatalization across different coronal consonants in various palatalization environments, represented by higher tongue contours in the front region, and more fronted tongue contours in the back region.

It is also clear that lexical and post-lexical palatalization yield different gestural patterns. However, the results observed here do not necessarily support the previous findings on lexical and post-lexical palatalization in other languages. In her articulatory and acoustic studies on English palatalization, [12, 13] claimed that the patterns of lexical palatalization tend to be categorical, while those of post-lexical palatalization tend to be gradient and yield more individualized trends. In this study, both lexical and post-lexical palatalization yield gradient, individualized patterns to some extent. Whether this discrepancy is caused by language-specific properties of palatalization needs to be further examined with more speakers, possibly coupled with the acoustic properties of palatalization.

Despite the preliminary results based on 4 speakers, the findings from this study leave open the possibility of dialectal differences in Korean palatalization. Given the fact that speaker 2 is the only Seoul speaker in this study and consistently shows different gestural patterns from other speakers, a follow-up study on dialectal differences in Korean palatalization could test whether the above-discussed gestural characteristics are dialectal or specific to individual speakers.

In sum, this study provides articulatory evidence for different types of palatalization and morphological structures of words. The results from the study also fit in with a large and growing body of evidence that speaker-specific variability exists in various phonetic and phonological phenomena [14, 15].

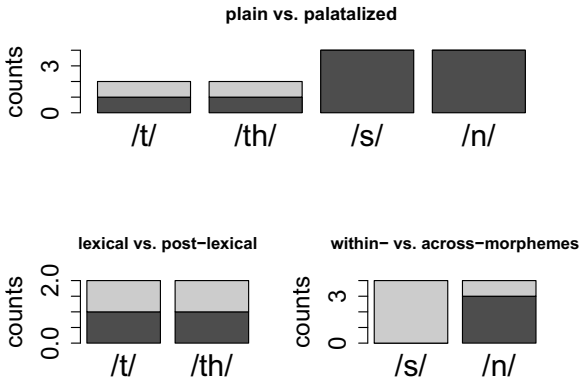

Figure 10: *A summary of the results: dark gray represents the number of speakers who showed significantly different tongue contours between two conditions, and light gray represents the number of speakers who did not.*

5. Acknowledgements

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