Stroboscopic-cine MRI and Acoustic data on gradual tongue movements in Korean Palatalization: Implications for its coarticulatory effect

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ABSTRACT

The present study addresses the question of whether the tongue rises as high as in the vowel /i/ in two types of Korean palatalization: a) when consonants occur before /i/ within a morpheme and b) when the consonants /t, t^h/ occur before /i/ across a morpheme boundary, changing into their affricate counterparts. For this purpose, we looked into stroboscopic-cine magnetic resonance imaging (MRI) data on tongue movements taken from two native speakers of the Seoul dialect. The MRI results that the tongue gradually rises and moves front throughout the target consonants are further confirmed by our acoustic data taken from ten Seoulites including the subjects in the MRI experiment. From this, we propose that Korean palatalization is a phonetic coarticulatory effect in the sense of Öhman [7] and Keating [3].

Keywords: Korean palatalization, coarticulation

1. INTRODUCTION

Korean palatalization has been assumed to be phonological with two processes (e.g., [1], [2]). In one process called postlexical palatalization, consonants are assumed to automatically change into postalveolar before the vowel /i/ within a morpheme (e.g., /mati/ -> [ma.t^ji] 'knot'). The other process is the lexically derived palatalization whereby the alveolar plosive consonants /t, t^h/ change into their postalvolar affricate counterparts before the vowel /i/ across a morpheme boundary (e.g., /mat+i/ [ma.dʒi] 'first child'). In the account of the two types of palatalization, the tongue has been proposed to move front and rise toward the hard palate as much as in the vowel /i/ and the change of the tongue position has been given a formal account as feature-changing (e.g., [6]). In the present study, we raise the question of whether Korean palatalization is such a phonological process. This question is partially motivated by recent studies showing that Korean affricates are not postalveolar, but alveolar just like the coronal plosives /t, t^h, t'/ in support of Skalická [8] ([5]) and that the change of /t, t^h/ into alveolar affricates before the vowel /i/ across a morpheme boundary is the phonological process of assibilation ([4]). So in order to investigate the status of the two types of Korean palatalization, we conducted a stroboscopic-cine MRI and an acoustic experiment, and examined tongue movements.

2. STROBOSCOPIC-CINE MRI DATA

The MRI experiment was performed on a Shimadzu Marconi Eclipse Power Drive 250 (=1.5[T]) at Advanced Telecommunications Research Institute, Kyoto, Japan. Two middle-aged native speakers (one male and one female) speaking the Seoul dialect participated in the experiment. Each MRI image for midsagittal data of our two subjects' head and neck has a 256 mm x 256 mm field of view with a 10 mm slice thickness, mapped on to 256(x) x 256(y) pixels. Each trigger pulse signals the MRI controller to begin the field echo scans (TR=16.5 ms, TE=3 ms, NEX=1) repeated 52 times every 16.7 ms (60 frames/sec) for one of the 128 gradient magnetic field conditions which is maintained for each 1000 ms period and changed at each trigger pulse. During data acquisition, the subjects repeated 128 times the seven test words in Table 1 and thus 128 MR scans for each of 52 sequential midsagittal frames were collected. The repetitions needed to be perfectly synchronized with MRI scanning in order to retain high quality motion imaging. To facilitate the synchronization, trigger generator software on a PC was used two types of signals: trigger pulses to initiate MRI scans and tone bursts for the subjects. The obtained images were displayed on a computer screen with 8-bit gray-scale resolution for analysis.

Table 1: Test words

a.	/mat+i/	'first child'		
b.	/mati/	'knot'	/matsi/	(nonsense word)
	/mat^{h}i/	(nonsense word)	/mats^{h}i/	(nonsense word)
	/mat'i/	(nonsense word)	/mats'i/	(nonsense word)

As shown in Figure 1, we measured the distance between the highest part of the hard palate and the tongue body for tongue raising (a), and the distance between the tongue root and the pharyngeal wall for tongue fronting (b), as a function of time.

Figure 1: Measurements for tongue raising (a) and for tongue fronting (b).

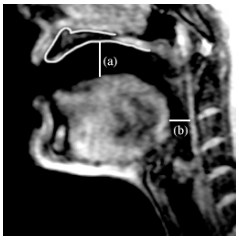
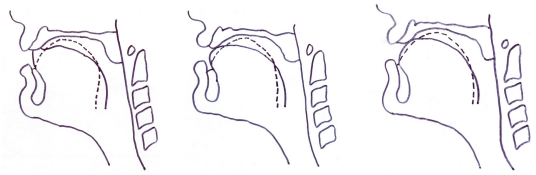


Figure 2 presents overlays of traced tongue contours of the consonants /t, t^h, t', ts, ts^h, ts'/ in /ma_i/ and the lexically-derived affricate in /mat+i/ at closure onset (marked with a solid line) and at the vowel /i/ (marked with a dotted line) from our female (i) and male (ii) subjects. In the examined contexts, we can note that, at the beginning of a consonant, the tongue does not rise as high as in the following vowel /i/ and it does not move as front as in the vowel, either.

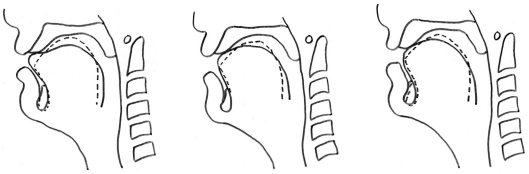
Figure 2: Overlays of traced tongue contours of the consonants /t, t^h, t', ts, ts^h, ts'/ from our female (i) and male (ii) subjects.

a. /mati/ b. /matsi/ c. /mat+i/

i.

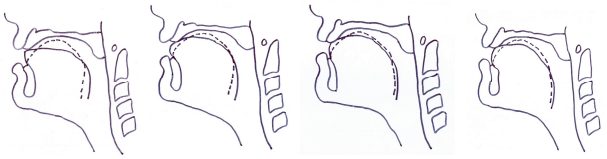


ii.

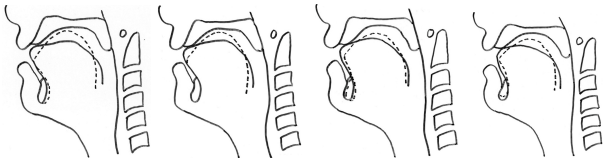


d. /mat^hi/ e. /mat'i/ f. /$mats^h$i/ g. /mats'i/

i.



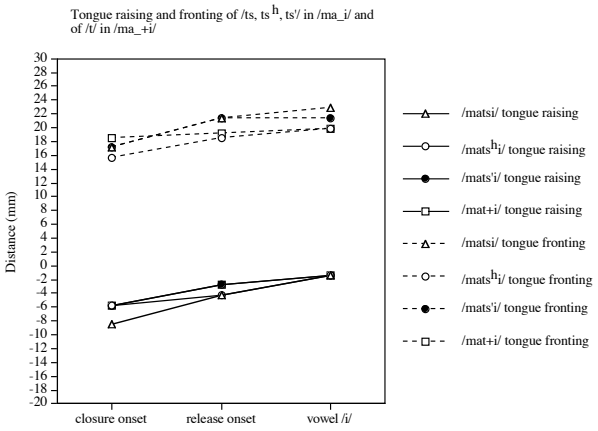
ii.



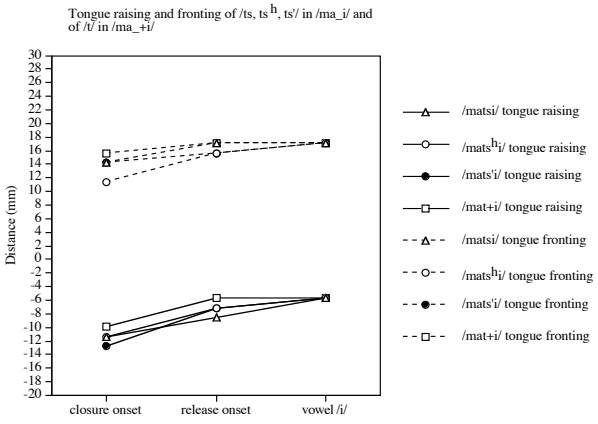
In order to more clearly see how the tongue rises and fronts from the consonants to the vowel /i/ as a function of time, we measured the distance for tongue raising, and for tongue fronting, as in Figure 1, from the closure onset of the consonants through the release to the vowel onset. The resultant figure is in Figure 3. Note that zero value in the *y*-axis indicates the tongue contact against the hard palate. So negative values along the *y*-axis refer to how far the tongue is below the hard palate, and thus their absolute values indicate the distance from the hard palate in tongue raising. It is noteworthy that, in our two subjects, the tongue body gradually rises toward the hard palate and move front from the consonants to the following vowel /i/, no matter whether they are within a morpheme or across a morpheme boundary.

Figure 3: Tongue raising and fronting at the closure and release onsets of consonants and the vowel onset in /matsi, $mats^h$i, mats'i, mat+i/ from our female (a) and male (b) subjects.

a.



b.



3. ACOUSTIC DATA

Given the above articulatory data, we may expect F_1 and F_2 values for tongue raising and fronting, respectively, to be gradient in both the tautomorphemic consonants and the lexically-derived alveolar affricate in /mat+i/ 'first child' in acoustic data. In order to check this, we conducted an acoustic experiment and examined how vowels

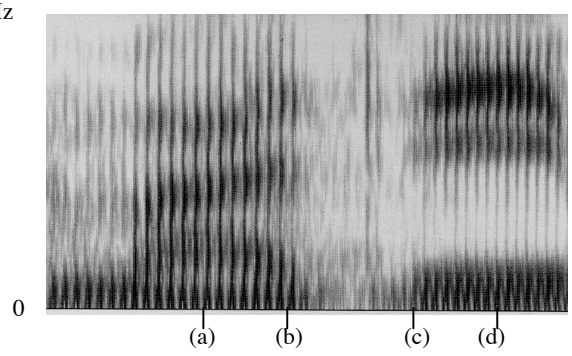
neighboring the consonants are acoustically realized in F_1 and F_2 values.

Table 2: Test words

a. /mati/ 'knot' /matsi/ (nonsense word) /mat+i/ 'first child'	
b. /mata/ 'every' /matsa/ (nonsense word) /mita/ 'to tear a hole' /mitsa/ (nonsense word) /miti/ (nonsense word) /mitsi/ (nonsense word)	

The target consonants /t, ts/ were in the contexts /a_(+)i/ in Table 2 (a), as in our MRI data, and also in /a_a, i_a, i_i/, as in Table 2 (b). The test words were put in the frame sentence /nɛka__ palɨmhapnita/ 'I pronounce __' and the sentences were read four times at normal speed by ten speakers (five males and five females) including the two subjects in the above articulatory experiment, all of whom commanded the Seoul dialect. The test words were tape-recorded and the total 360 tokens (9 test words x 10 subjects x 4 repetitions) were then analyzed. In order to investigate whether or not the lexically-derived lenis affricate and the underlying consonants /t, ts/ before the vowel /i/ have tongue raising and fronting as much as the high front vowel, we investigated F_1 and F_2 frequency values of vowels adjacent to a target consonant. As shown in Figure 4, we put a cursor at the four points — (a) at the midpoint of the vocalic period in the first vowel, (b) at the end of the first vowel, (c) at the onset of the second vowel, (d) at the midpoint of the vocalic period for the second vowel — in wide-band spectrograms of the test words, to measure F_1 and F_2 values.

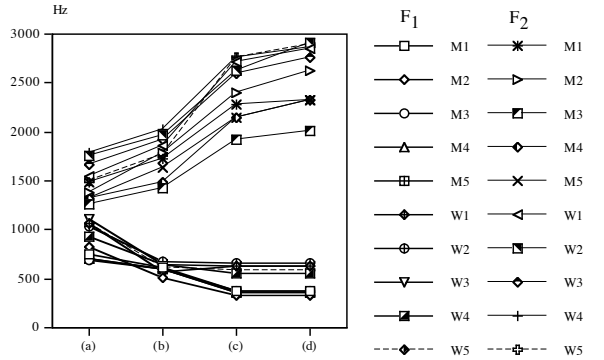
Figure 4: Cursor placements for an F_1 and F_2 transition analysis in /mati/ 'knot'



We examined whether a vowel preceding or following a target consonant would show vowel-to-vowel transition or not. If the vowel does not show vowel-to-vowel transition, no matter whether it is preceded or followed by /a/ or by /i/ across the target consonant, the consonant would be expected to have the same tongue fronting and raising as the vowel /i/. If there is transconsonantal vowel-to-vowel transition in the same contexts, the target consonants would be expected to have no tongue raising and fronting like the vowel /i/. Figure 5 shows the average of the F_1 and F_2 values at the four measured points in the four tokens of the test words /mati/ (a), /matsi/ (b) and /mat+i/ (c) spoken by our ten subjects.

Figure 5: The transition of the average first and second formants at the four examined points in /mati/ (a), /matsi/ (b) and /mat+i/ (c).

a.



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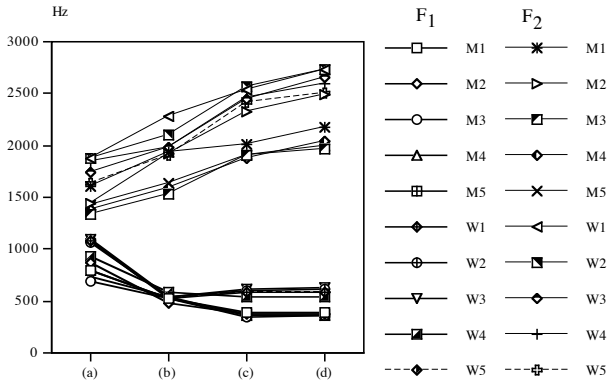
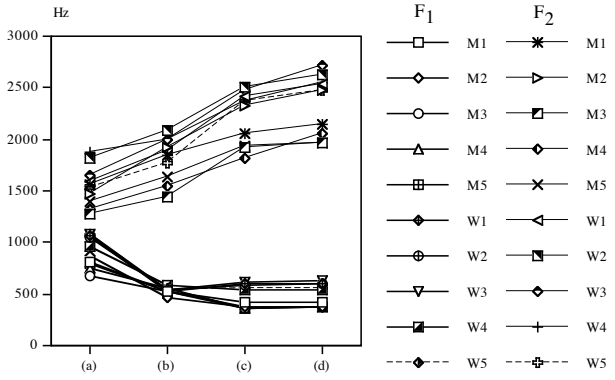
b.



c.



We can note that the second formant goes up gradually from the first vowel /a/, throughout the intervening consonants, to the following vowel /i/ across the ten speakers. On the other hand, the first formant begins to fall down gradually in the first vowel and throughout the intervening consonants.

The examination of F_1 and F_2 value difference in the first vowel of the control condition /a_a/ and the target condition /a_(+)i/ reveals that the vowel /a/ in the latter is affected by the following vowel /i/ across the plosive or affricate consonant. All the subjects had a bigger difference in the average F_1 and F_2 values in the first vowel /a/ when it is followed by the high front vowel /i/ than by the vowel /a/, regardless of whether an intervening consonant is an underlying plosive, affricate or a lexically-derived affricate. Pairwise two-tailed *t*-tests revealed that the average of F_1 and F_2 value differences between in the middle and at the end of /a/ preceding a target consonant is statistically significant, across the ten subjects, in the comparision of /mat+i/ and /matsa/ ($t(9)=-10.6$, $p<0.0001$ for F_1; $t(9)=4.1$, $p<0.028$ for F_2), /matsi/ and /matsa/ ($t(9)=-9$, $p<0.0001$ for F_1; $t(9)=-5.9$, $p<0.0002$ for F_2), and also /mati/ and /mata/ ($t(9)=-5.5$, $p<0.0004$ for F_1; $t(9)=5.6$, $p<0.0003$ for F_2). From this, we can say that the intervening consonants are transparent to vowel-to-vowel transition in /a_(+)i/ (vs. /a_a/), regardless of the underlying lenis plosive, affricate or the lexically-derived lenis affricate. A similar transition of the first and second formants is also observed in the vowel /a/ following the vowel /i/ across the underlying plosive and affricate in the test words /mita/ and /mitsa/.

4. CONCLUSION

In order to investigate whether the two types of Korean palatalization are phonological, we have examined stroboscopic-cine MRI data of the coronal consonants /t, t^h, t', ts, ts^h, ts'/ in the context /ma_i/ and /t/ in /ma_+i/ and acoustic (i.e. F_1 and F_2 transitions in wide-band spectrograms) data of the coronal plosive /t/ and the lexically-derived and underlying affricates /ts/ in /ma_a, ma_(+)i, mi_a, mi_i/. From our MRI data, we have noted that the tongue gradually rises and moves front throughout the consonants up to the following vowel /i/. The gradual tongue fronting and raising have been confirmed in our acoustic data in which transconsonantal vowel-to-vowel transition was observed in F_1 and F_2 values in the sense of Öhman [7].

Based on the present phonetic results, we propose that Korean palatalization is a phonetic coarticulatory effect of the following vowel /i/, regardless of a morpheme boundary, in Öhman's [7] transconsonantal vowel-to-vowel transition model and Keating's [3] target-interpolation (or window) model. That is, a consonant before the vowel /i/ is phonologically unspecified for tongue raising ([+high]) and fronting ([-back]) which acoustically correlate with F_1 and F_2, respectively, and remain unspecified for the features throughout phonetic implementation. Due to the transparent consonant which is unspecified for tongue raising and fronting, the gradual tongue movements and the transconsonantal vowel-to-vowel transition take place, as shown in our present study. Consequently, Korean palatalization is a phonetic coarticulation, not a feature-changing phonological process with the division of lexical and postlexical palatalization.

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