

Coordinations of Articulators in Korean Place Assimilation

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ABSTRACT

This paper examines several articulatory properties of /k/, known as a trigger of place assimilation as well as the object of post-obstruent tensing (/tk/), in comparison to non-assimilating controls (/kk/ and /kt/). Using EMMA, tongue body articulation in the place assimilation context robustly shows greater spatio-temporal articulation and lower jaw position. Results showed several characteristics. Firstly, constriction duration of the tongue body gesture in C2 of the assimilation context (/tk/) was longer than non-assimilating controls (/kk/ and /kt/). Secondly, constriction maxima also demonstrated greater constriction in the /tk/ sequences than in the control /kk/, but similar values with the control /kt/. In particular, results showed a significant relationship between the two variables - the longer the constriction duration, the greater the constriction degree. Lastly, jaw height was lower for the assimilating context /tk/, intermediate for the control /kk/, and higher for the control /kt/. Results suggest that speakers have lexical knowledge of place assimilation, producing a greater tongue body gesture in the spatio-temporal domains with lower jaw height as an indication of anticipating reduction of C1 in /tk/ sequences.

Keywords: place assimilation, post-obstruent tensing, articulation, tongue dorsum, jaw, gestural overlap, gestural reduction

1. Introduction

Korean shows optional place assimilation in which either a labial /p/ or a coronal /t/ is assimilated to the following dorsal /k/. This is known to be sensitive to speech rate, but not word boundary conditions (Jun, 1996, 2004).

(1) Place assimilation rule (Jun, 1996)²⁾

/mit + ko/ → [mitko] or [mikko] ‘believe and’
/ip + ko/ → [ipko] or [ikko] ‘wear and’

In Korean phonology, fortition is also involved in the production of a trigger stop consonant in place assimilation. In the examples in (1), a tense /k/ is produced after the post-obstruent tensing rule is applied³⁾ (Kim-Renaud, 1974).

(2) Post-obstruent tensing rule

/mit + ko/ → [mitk*o] or [mikk*o] ‘believe and’
/ip + ko/ → [ipk*o] or [ikk*o] ‘wear and’

Given these two rules, generative grammar has traditionally explained that the output form was derived from a serial application of rewrite rules, whereby tense [k*] occurs as the second consonant as shown in (2). In addition, Korean obstruents are unreleased in word-final position and before a following consonant (Kim-Renaud, 1974).

(3) Unreleased obstruent rule

/mit + ko/ → [mitk*o] or [mikk*o] ‘believe and’
/ip + ko/ → [ipk*o] or [ikk*o] ‘wear and’

However, the output form resulting from the serial application of rewrite rules needs some device so as to be delivered from speakers to listeners. Without much discussion, generative grammar assumed that the output in the surface representation served as the input in a universal implementation rule (Chomsky and Halle, 1968). Under this account, different outputs in the form of [kk*] are supposed to demonstrate similar phonetic

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2) Broad phonetic transcription is employed in Jun (1996).

3) The symbol ‘*’ represents a tense/fortis stop.

characteristics regardless of different input forms.

However, in an acoustic study, it was shown that an inherent /k*/ exhibited longer closure duration than derived [k*] (/Vk+k*V/ to [Vkk*V] vs. /Vk+kV/ to [Vkk*V]), the former being longer than an intervocalic fortis (/V+k*V/) as well (Ahn, 2004). What is interesting for Ahn is that an inherent [k*] is longer in closure duration than a derived [k*] when they are identically preceded by a coda /k/. This is counterevidence for Chomsky and Halle's (1968) assumption that the same surface forms are universally realized without showing a difference.

With respect to phonetic cues relating to place assimilation outlined above in (1), *internal cues*, which are more directly associated with the consonantal constriction, were directly examined in some articulatory studies, showing that fortis (/p*/ or /t*/) was spatio-temporally produced with stronger articulation than lenis (Cho & Keating, 2001; Son & Cho, 2010). Comparable to articulatory correlates, acoustic studies also showed longer closure duration in fortis than in lenis (Cho et al., 2002). *External cues* of stop consonants have also been examined well. With respect to phonetic cues relating to the post-obstruent tensing, acoustic measures such as H1-H2, H1-F2, F0, intensity rise time, RMS, etc. were taken to indicate different laryngeal configurations as external cues (Cho et al., 2002; Ahn, 2004, among others).

Recent studies based on laboratory experiments have shown that assimilation can be understood in part as spatio-temporal reduction of the target stop consonant in speech production. This process is known to be a near categorical process (Jun, 2004, Kochetov & Pouplier, 2008). Another crucial hypothesis is gestural overlap by which segments are not sequentially lined up in production, but they are inherently overlapped to varying degrees (Mattingly, 1981; Liberman, Cooper, Harris, MacNeilage, & Studdert-Kennedy, 1967). Under the hypothesis of Articulatory Phonology (Browman & Goldstein, 1989, 1991), kinematic aspects of the articulation can be examined from the perspective of space (constriction degree) and time (constriction location). In defining the basic unit of phonology known as a "gesture" (a linguistically meaningful event), a set of articulators are said to be involved in producing segments as a coordinative structure (Saltzman, 1986). For example, the jaw articulator is commonly shared either with the lips (labials), the tongue tip (coronals), or the tongue dorsum (dorsals) (Browman & Goldstein, 1991). Specifically, voiceless coronal /t/ demonstrates higher jaw position and its dorsal counterpart /k/, lower jaw position (Keating et al., 1994).

Taking into account speech articulation from the perspective of

gestural reduction, gestural overlap, and a coordinative structure, the research questions addressed in the current study are whether, and if so, how derived [k*] in the assimilating context (/tk/) is phonetically realized in a manner different from its counterparts in the non-assimilating context (/kk/) and the unreleased coda (/kt/).

1.1 Research questions

The first question to be addressed is whether, and if so, how the tongue dorsum gesture differs among three different sequences in time. Although derived [k*] from /kk/ sequences was shown to be acoustically shorter than inherent [k*] from /kk*/ sequences (Ahn, 2004), nothing substantial about [k*] in assimilating or non-assimilating contexts has been discovered before this study. In the current study, constriction duration of the tongue dorsum gesture is examined between the assimilating context (/tk/ to [kk*]) and the homorganic sequence control (/kk/ to [kk*]). Along with this, the unreleased lenis coda [k] of /kt/ sequences is examined as another control. If universal phonetic implementation is true for Korean post-obstruent tensing, it should exhibit similar duration between the assimilating context and the homorganic control, which in turn should show longer constriction duration than the unreleased lenis stop [k] of /kt/ sequences.

Next, spatial magnitude of the tongue dorsum gesture will be examined to show whether, and if so, how it may vary depending on different cluster types - the assimilating context (/tk/) vs. the control homorganic context (/kk/) vs. the control unreleased coda context (/kt/). Investigating oral and laryngeal gestures, Romero (1999) showed relationship between time and space; the longer the constriction duration in the oral context, the greater the glottal gesture. Since this spatial aspect of the tongue dorsum gesture, the trigger of pexce assimilati/kk/has not been directly measured using other methodologies using acoustic and EPG studies, I will therefore examine constriction degree in the assimilation context in comparison to the controls.

Lastly, I will examine whether, and if so, how the jaw articulator is coordinating with the tongue dorsum articulator depending on different cluster types stored distinctively in the lexicon. Since inter-gestural overlap is greater in the assimilating context than in the non-assimilating context (Son, 2008), it is possible for unassimilated /tk/ to demonstrate higher jaw position than non-assimilating /kt/. However, if there is frequent reduction of C₁ /t/, which results in assimilation (Kochetov and Pouplier, 2008), it is possible to expect that jaw position in the assimilation context is not as high as the control /kt/ where /t/ is

realized without reduction. Likewise, the underlying control /kk/ sequence may exhibit lower jaw position in comparison with non-assimilating control /kt/ sequences since it does not contain an initial tongue tip gesture.

2. Method

EMMA (Electromagnetic Midsagittal Articulator) is used to collect articulatory data from pellet movement (Perkell, Cohen, Svirsky, Matthies, Garabieta, & Jackson, 1992) - i) four pellets were attached to the tongue with approximately equal distances from the tongue tip to the tongue dorsum and ii) two pellets were attached to the upper and lower lips and one to the lower incisor. Two pellets attached to the nose bridge and the upper incisor were used as reference points for head correction. The occlusal plane was obtained from two additional pellets attached to a plastic plate (i.e. bite plate). Post-processing procedures were applied b tip tthe final data set was ready for further analysis. The raw data were dynssically rotated as the occlusal plane was used as the x-axis, for fure y-axis at 90 degrees from it (Westbury, 1994). Kinematic data were sampled at 500 Hz and smoothed by a low-pass filter of 15 Hz. Figure 1 shows the location of pellets superimposed on a view of the midsagittal plane of a sketched face.



Figure 1. Locations of pellets: (a) the tongue dorsum; (b) tongue body 2; (c) tongue body 1; (d) the tongue tip; (e)-(f) the maxillary (upper) and mandibular (lower) central incisors; (g)-(h) the upper and lower lips; and (i) the nose bridge.

2.1 Subjects and speech material

Seven native speakers of Seoul-Korean, four female and three male, participated in production experiment - they spent at least their first 19 years in the Seoul or Gyeonggi-do regions. They

were residing in New Haven, U.S.A. for their graduate studies or postdoctoral research. None of them suffered from speech impairment.

Stimuli included one target /Vt+kV/ sequence and control /Vk+kV/ and /Vk+tV/ sequences, each carried in a different natural-sounding sentence which was short in length. Speech material on a computer screen were presented to the speakers, who were asked to read naturally at a given speech rate as instructed (fast or comfortable). Each stimulus was read four times in a row, which was repeated twice. A total of 328 tokens were collected for further analysis (3 (Cluster Type) x 8 (Repetition) x 2 (Speech rate) x 7 (speakers)). Due to technical problems, /tk/ sequences at fast rate produced by Subject 7 were not available.

(4) Stimuli list

a. /pepat^hkaesə pe cuassci/

‘(I) picked up pear(s) on the side of a pear orchard.’

b. /cənhak^hkanin seloun tehaklo ilimija/

‘Ceonhak Street is a new university street name.’

c. /əhaktapin nonsullo heyatoi/

‘(You) should give essay responses in the verbal section.’

2.2 Data analysis

The vertical tongue dorsum gesture (TD) was analyzed using an algorithm on the basis of a velocity threshold. In order to compare tongue body gestures in three different phonological contexts, constriction duration of the tongue dorsum gesture and its maximal constriction were measured using MVIEW (Tiede, 2005) (see more details, Son et al. 2007; Kochetov & Pouplier, 2008). In addition, vertical jaw position, being aligned with the constriction maximum of the tongue body, was also measured. In the following are the relevant kinematic measures of the tongue dorsum and the jaw, to which I referred during measurement.

(a) Constriction onset (lip closing onset) (Fig. 2a).

(b) Constriction maxima during the lip constriction (Fig. 2b).

(c) Constriction offset (lip opening onset) (Fig. 2c).

(d) Constriction duration from lip constriction onset (left edge) to lip constriction offset (right edge) onset (Fig. 2d)

(e) The actual vertical jaw position (jaw height) at the constriction maxima of the lip constriction (Fig. 1e).

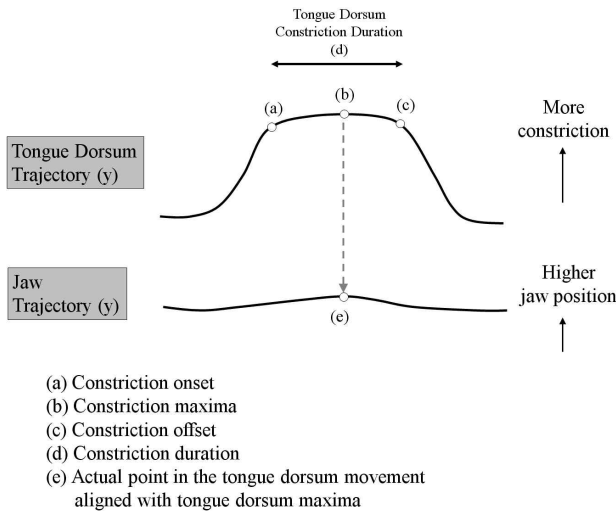


Figure 2. Schematized vertical tongue dorsum movement trajectory and vertical jaw movement trajectory with an actual point taken from the alignment point in vertical tongue body movement trajectory.

2.3 Statistical analysis

Repeated measures analyses of variance (RM ANOVA) were conducted (Max & Onghena, 1999). For each subject, each data point corresponds to the mean score of each tongue dorsum gesture in different phonological contexts. F-ratios and p-values generated from Huynh-Feldt corrected degrees of freedom and error terms were reported ($p < 0.05$) (Huynh & Feldt, 1970). Posthoc pairwise comparisons were carried out every time difference between factors needs to be determined. Using Pearson product-moment correlation and linear regression coefficients, the possibility of correlation between the two variables are investigated.

3. Results

There was a main effect of Cluster type for spatio-temporal properties of the tongue dorsum gesture and jaw height ($p < 0.05$). However, a main effect of Speech rate was only observed for the constriction duration. No Cluster type x Vowel interaction was found.

3.1 Spatio-temporal properties of the tongue dorsum

3.1.1 Constriction duration

Examining tongue dorsum gestures in three different contexts (/tk/ vs. /kk/ vs. /kt/), there was a main effect of Cluster type. Seoul-Korean speakers exhibited longer constriction duration in

the assimilation context (/tk/) than control homorganic sequences (kk/) or control unreleased coda (/kt/), the latter two showing similarity in constriction duration (/tk/ > (/kk/=/kt/)) [$F(1.5,7.4)=7$, $p < 0.05$]. There was also a main effect of Speech rate, where longer constriction duration was observed in comfortable rate [$F(1,5)=19.56$, $p < 0.05$].

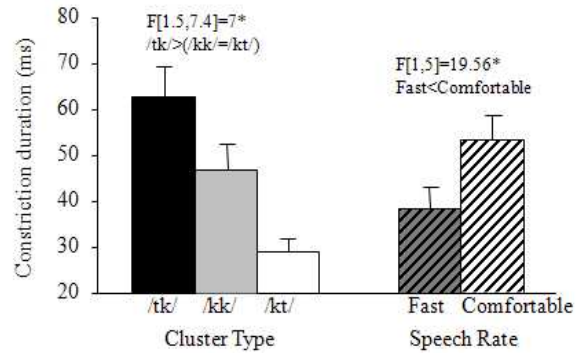


Figure 3. Constriction duration of the tongue dorsum gesture (Note that * refers to $p < 0.05$).

As shown in Figure 3, constriction duration of the tongue dorsum gesture in the assimilation context is remarkably longer than the homorganic /kk/ sequences or the unreleased velar in the coda. This may indicate that speakers could have produced longer constriction duration, resulting in a compensation for a frequently reduced tongue tip gesture in C₁.

3.1.2 Constriction maxima

Constriction maxima of the tongue dorsum gesture exhibited a greater constriction in the assimilation context (/tk/) than in the control homorganic sequences (/kk/) [$F(2,10)=4.28$, $p < 0.05$]. Other comparisons showed no difference in degree of constriction. There was no main effect of Speech rate ($p > 0.05$).

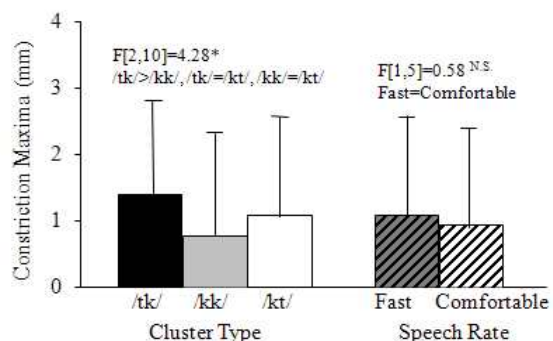


Figure 4. Constriction maxima of the tongue dorsum gesture (Note that * refers to $p < 0.05$).

3.1.3 Constriction maxima

There is a relationship between constriction duration and constriction maxima in the tongue dorsum gesture produced within the supralaryngeal cavity; the longer the tongue dorsum gesture, the greater its magnitude ($r=0.135$, $p=0.015$). In an analysis of linear regression, the constriction duration explained a significant proportion of variation in constriction maxima [$R^2=0.018$, $F(1,326)=6.02$, $p=0.015$].

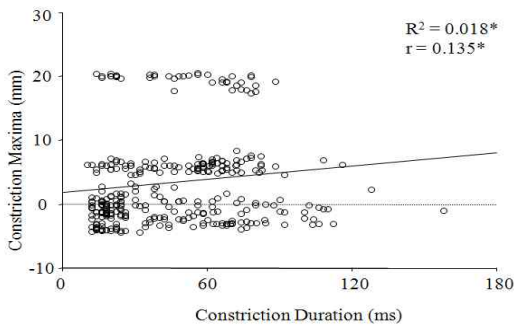


Figure 5: Relationship between constriction duration and constriction maxima.

3.2. Vertical jaw position

Jaw position differed, showing that it was lower for the assimilation context (/tk/), intermediate for the control homorganic sequence (/kk/), and higher for the control /k/ in the coda (/kt/) [$F(1.3,6.4)=12.46$, $p<0.05$]. No speech rate effects on jaw position were found ($p>0.05$).

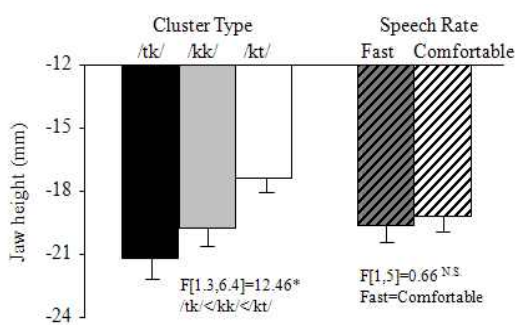


Figure 6. Actual jaw position aligned with tongue dorsum maxima (Note that * refers to $p<0.05$).

Jaw height and constriction maxima were also related ($r=0.66$, $p<0.0001$) - jaw height explained a significant portion of variation in constriction maxima [$R^2=0.44$, $F(1,326)=25.3$, $p<0.0001$].

4. Discussion and conclusion

4.1 Stronger tongue dorsum gesture in the assimilating /tk/ context

The results showed that constriction duration of the tongue dorsum gesture was longer in the assimilating context (/tk/) than in the contexts of two consecutive dorsal consonants (/kk/) or an unreleased dorsal coda (/kt/). Previous articulatory studies on Korean place assimilation have been focused on the gestural reduction of C_1 or gestural overlap between C_1 and C_2 , paying almost no attention to articulatory events in C_2 (Jun, 2004; Kochetov & Pouplier, 2008; Son, 2008; Son et al., 2007). The present study clearly suggests that phonetic implementation of the output form stemming from a different input form is dependent on different lexicons, but not governed by universal phonetic implementation, referring to different inputs of the underlying representation (see English palatalization as lexicon-dependent variation in the phonetic execution level ('confession' vs. 'confess your' in Zsiga (1995)). That is, temporal constriction duration of the tongue dorsum gesture was markedly longer for the assimilating /tk/ sequences. As for spatial magnitude of the tongue dorsum gesture, the results showed that there was greater constriction in the assimilating /tk/ sequences than the control homorganic /kk/, but similar to sequences of the opposite order, /kt/. The last two control sequences were not different. There was a relationship between time and space, showing that longer constriction duration is associated with greater constriction ($r=0.135$). Speech rate effects were only limited to temporal aspects of the tongue dorsum gesture, implying that the fast rate is related to shorter constriction duration and comfortable rate to longer constriction duration.

To sum up, if spatio-temporal properties are both taken into account, it was the assimilating sequence (/tk/) that demonstrated stronger articulation. These results are in line with compensatory lengthening in autosegmental phonology where place assimilation was accounted for by means of representations with delinking and re-association lines (Clements, 1985; Hayes, 1992; Nolan, 1992). Nevertheless, this approach, relying on the representation *per se*, does not succeed in giving a satisfactory account of different phonetic implementations for the two given segmental slots across different sequences (e.g., /tk/ to [kk*]; /kk/ to [kk*]). Alternatively, Articulatory Phonology (Browman & Goldstein, 1989, 1991), may better embrace different durational and spatial characteristics of the tongue dorsum between /tk/ and /kk/ in the phonetic implementation level since it hypothesizes that time and space are inherent components of a gesture. As a possible reason

for stronger articulation of /tk/ at the phonetic execution level, it seems as if speakers have knowledge of the place assimilation process. The temporal tongue dorsum gesture in [kk*] derived from assimilating /tk/ sequences brought in as a way to reflect reduced /t/ of C₁ upon C₂, which results in longer constriction duration (see morpheme boundary effects for different lexical entries in Cho (2001)). By doing this, speakers may still endeavor to convey lexical information so that listeners are able to use longer and stronger articulation of the tongue dorsum as perceptual cues and retrieve underlying lexicons. In this way, neutralization did not occur in two different lexical entries.

4.2 Jaw position

As for jaw height, the results showed lower jaw position for /tk/, intermediate for /kk/, and higher for /kt/ (/tk/ < /kk/ < /kt/). Since a voiceless coronal stop /t/ is associated with higher jaw position than a velar /k/ (Keating et al., 1994; Tuller, Harris, & Gross, 1981), it is plausible to expect higher jaw position in the adjacent /k/ if it is more overlapped with /t/. However, /tk/ sequences, known to be more overlapped (assimilation context), exhibited lower jaw position than the opposite order, /kt/, known to be non-assimilating and less overlapped (Son, 2008).

Taken together, there was spatio-temporal strengthening in the assimilating /tk/ sequences, but the jaw articulator was rather reduced in this context when compared to the control homorganic /kk/. Although the jaw articulator seems to pattern somewhat aberrantly with respect to the tongue dorsum articulator at first glance, the motive for this can be found in speakers' knowledge of the place assimilation process again such that the tongue tip gesture in the assimilating /tk/ sequences is frequently reduced (Kochetov and Pouplier, 2008). Possibly due to this, speakers may not have moved the jaw as much as they did for the control /kk/ or /kt/ sequences as they anticipated articulatory reduction in the tongue tip gesture, which in turn had influenced on the lower jaw position aligning with the tongue dorsum maximum time point. Overall, the present study indicates that articulatory strengthening in the tongue dorsum gesture of C₂ and articulatory reduction in the jaw gesture cooperate so as to coherently result in articulatory reduction in C₁ as well as strengthening in C₂ as a coordinative structure.

4. Conclusion

This study showed spatio-temporal properties of the tongue dorsum articulator as well as the jaw articulator, examining the

assimilating /tk/ sequence, control homorganic /kk/ sequence, and unreleased /kt/ sequence. Results showed that the /tk/ sequence was distinguished from the controls (/kt/ and /kk/) in three variables (constriction duration, constriction maxima, and jaw height). The tongue body gesture in C₂ showed strengthening in the assimilating context, but lower jaw position hinted at gestural reduction of C₁. The results suggest that Korean speakers have knowledge of place assimilation process, moving articulators in a coordinative manner in speech production in order to convey, even if distorted, lexical information pertaining to place assimilation.

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