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A Language-Specific Physiological Motor Constraint in Korean Non-Assimilating Consonant Sequences

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ABSTRACT

This paper explores two articulatory characteristics of inter-consonantal coordination observed in lingual-lingual (/kt/, /ks/) and labial-lingual (/pt/) sequences. Using electromagnetic articulometry (EMMA), temporal aspects of the lip movement and lingual movement (of the tongue tip and the tongue dorsum) were examined. Three sequences (/ks/, /kt/, /pt/) were investigated in two respects: gestural overlap in C1C2 and formation duration of coronals in C2 (/t/ or /s/). Results are summarized as follows. First, in a sequence of two stop consonants gestural overlap did not vary with order contrast or a low-level motor constraint on lingual articulators. Gestural overlap between two stop consonants was similar in both /kt/ (lingual-lingual; back-to-front) and /pt/ (labial-lingual; front-to-back). Second, gestural overlap was not simply constrained by place of articulation. Two coronals (/s/ and /t/) shared the same articulator, the tongue tip, but they showed a distinctive gestural overlap pattern with respect to /k/ in C1 (/ks/ (less overlap) < /kt/ (more overlap)). Third, temporal duration of the tongue tip gesture varied as a function of manner of articulation of the target segment in C2 (/ks/ (shorter) < /kt/ (longer)) as well as a function of place of articulation of the segmental context in C1 (/pt/ (shorter) < /kt/ (longer)). There are several implications associated with the results from Korean non-assimilating contexts. First, Korean can be better explained in the way of its language-specific gestural pattern; gestural overlap in Korean is not simply attributed to order contrast (front-to-back vs. back-to-front) or a physiological motor constraint on lingual articulators (lingual-lingual vs. nonlingual-lingual). Taking all factors into consideration, inter-gestural coordination is influenced not only by C1 (place of articulation) but also C2 (manner of articulation). Second, the jaw articulator could have been a factor behind a distinctive gestural overlap pattern in different C1C2 sequences (/ks/ (less overlap) vs. /kt/ and /pt/ (more overlap)). A language-specific gestural pattern occurred with reference to a physiological motor constraint on the jaw articulator.

Keywords: gestural overlap, inter-gestural coordination, jaw, Korean, lingual, non-assimilating, order contrast, physiological motor constraint

1. Introduction

In more recent studies, various phonological phenomena and language-specific phonotactics are attributed to inter-gestural coordination (Browman and Goldstein, 1989, 1992). In particular, consonantal gestures are distinctively coordinated in syllable-initial and syllable-final position (Nam, 2007). In syllable-initial position consonant clusters (C1C2) are competing relations with respect to the syllable nucleus vowel (Browman and Goldstein, 1988), while coda consonant clusters are aligned sequentially with respect to the preceding vowel. Examples are found in American English, French, and Georgian (Browman & Goldstein, 1988; Chitoran, Goldstein, & Byrd, 2002; Kühnert, Hoole, & Mooshammer, 2006). In addition, inter-gestural coordination of consonant clusters with flanking vowels is known to be sensitive to language-specific phonological phenomena. For example, an assimilating language (e.g., Korean) demonstrates more overlap

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between C1 and C2 compared to non-assimilating language (e.g., Russian) (Kochetov, Pouplier, & Son, 2007). Even within an assimilating language, assimilation contexts show more overlap than non-assimilation contexts (Son, 2008).

Although individual languages or a set of different languages have demonstrated distinctive inter-gestural coordination patterns, previous studies have proposed several articulatory constraints which could be influential in language-particular gestural patterns observed in a single language or among a certain subset.

Firstly, there was an order contrast. In syllable-initial position, Georgian and French have shown order effects in C1C2 sequences, showing that more overlap occurs in front-to-back sequences compared to the reverse order (Kühnert et al., 2006; Chitoran et al., 2002). For example, in stop-stop sequences, order contrast was attributed to transmission of phonetic cues (e.g., constriction release) of C1 in the front part of the oral cavity at any point in time during the articulation of C2 which is articulated in the rear of the vocal tract. Hence, a front-to-back sequence could exhibit more overlap. In contrast, the reverse order (back-to-front) would have partially or fully masked any phonetic cues of C1 if it were totally obscured by the closing of C2. Therefore, a back-to-front sequence tended to show less overlap.

Similar order effects were observed with sonorant coronals. When the manner of articulation in C1 was varied with labials (/p/, /f/) and a dorsal (/k/) in French, a nasal (/n/) or lateral (/l/) in C2 exhibited consistent order effects with respect to C1: more overlap in the front-to-back order (Kühnert et al, 2006). The result was suggestive of counterevidence for perceptual recoverability (Chitoran et al., 2002); although relevant phonetic cues of C1 followed by a sonorant sounds (/n/ or /l/) could be conveyed to listeners at any point of time during the production of C2 (Steriade, 1997), order contrast was observed nevertheless.

Secondly, as an alternative hypothesis, Kühnert et al. (2002) attributed this to a low-level physiological motor constraint which ensured that two adjacent lingual gestures demonstrate longer lag (i.e., less overlap) than nonlingual-lingual sequences. Inter-gestural coordination was also investigated with regard to temporal aspects of C2. In C1C2 sequences (/pn/, /fn/, /kn/, /pl/, /fl/, /kl/) Kühnert et al. (2006) showed that half of the subjects in their study demonstrated longer formation duration of a coronal sonorant (/n/ or /l/) only when it was preceded by a nonlingual C1 (/p/ or /f/), as compared to a lingual C1 (/k/). As a possible explanation, they attributed this to motor constraints acting upon a sequence of lingual-lingual clusters. That is, if a sequence involves holistic tongue movement, C1 could have constrained the articulation of C2 – by doing so, lingual movement of C2 (/n/, /l/) before a lingual segment in C1 (/k/) was not initiated as early as that in the context of a nonlingual segment in C1 (/p/, /f/).

Korean assimilating contexts did not show order contrast in gestural overlap (Son, 2008). A more comprehensive range of C1C2 sequences has yet to be explored, however, from the perspective of order contrast and motor constraints on holistic tongue movement in Korean. In this paper, it is of interest whether these two principles are active in Korean non-assimilating contexts when we vary place of articulation in C1 and manner of articulation in C2.

1.1 Research questions

In an articulatory study, Son (2008) showed order contrast was not observed when different assimilation context effects were factored out. For example, in assimilating contexts (/tk/ (front-to-back) vs. /tp/ (back-to-front)), both sequences demonstrated similar gestural overlap, using gestural onset-to-onset lag. By contrast, in non-assimilating contexts (/kt/ (back-to-front) vs. /pt/ (front-to-back)), there was more overlap as a function of order contrast, which showed more overlap in the former than in the latter (Kochetov et al., 2007). Korean, however, needs to be investigated in terms of inter-gestural coordination as we extend the scope of study to include different manners of articulation as was done with Georgian (Chitoran et al., 2002) and French (Kühnert et al, 2006). In this paper, as we replicate a gestural overlap study in Korean (/kt/ vs. /pt/) (Kochetov et al., 2007), our goal is to determine whether order effects or physiological constraints are present as we compare a stop-fricative sequence (/ks/) with stop-stop sequences (/kt/, /pt/).

In previous articulatory studies, it has been reported that formation duration of a lingual gesture in C2 can be longer if C1 is nonlingual. According to Kochetov et al. (2007), who referred to physiologically constrained, low-level motor constraints, a nonlingual (labial) gesture in C1 was less likely to constrain a lingual gesture in C2 compared to a sequence of lingual-lingual sequence. We examine in particular whether, and if so, how tongue tip gestures vary in formation duration as a function of different manner of articulation (fricative /s/ vs. stop /t/).

We pursue the research interests addressed above, limiting the scope of study to Korean non-assimilating contexts (/ks/, /kt/, /pt/). By dong this, we aim to characterize whether Korean can be better accounted for with reference to language-specificity or language-universality.

2. Method

EMMA (Electromagnetic Midsaggital Articulometer) (Perkell, Cohen, Svirsky, Matthies, Garabieta, & Jackson, 1992) is employed in this study. Articulatory data of pellet movement was collected with the pellets attached to speech articulators to track their dynamic motions - i) four pellets were attached to the tongue (the tongue tip, the front tongue body, the rear tongue body, the tongue dorsum), ii) one pellet was attached to each of the upper and lower lip, and iii) one pellet was attached to the lower incisor for referencing jaw movement. We used two pellets attached to the nose bridge and the upper incisor as reference points for head correction. The occlusal plane was obtained from two additional pellets attached to a plastic plate at the beginning of the experiment session. Post-processing procedures were applied as we dynamically rotated the raw data with the reference to the occlusal plane as the x-axis (Westbury1994). Kinematic data was sampled at 500 Hz and smoothed with a 15 Hz low-pass filter. In Figure 1, we show the location of pellets superimposed on a view of the midsagittal plane of a face. Acoustic data was acquired synchronously with a Sennheiser directional microphone at the time of the kinematic experiment.

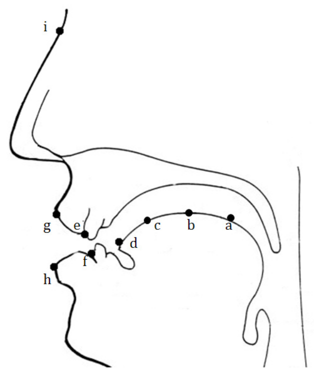

Figure 1. Locations of pellets: (a) the tongue dorsum; (b) tongue body 2; (c) tongue body 1; (d) the tongue tip; (e)-(f) the maxillary (upper) and mandibular (lower) central incisors; (g)-(h) the upper and lower lips; and (i) the nose bridge.

2.1 Subjects and speech material

Six native speakers of Seoul-Korean, three female and three male, participated in the EMMA experiments. They were residing in New Haven, CT, U.S.A. for their graduate studies or postdoctoral research and had spent their first 18 years in the Seoul/Gyeonggi-do areas. None of them suffered from speech or hearing deficits.

Stimuli included three target sequences (/a**k**+**s**a/, /a**k**+**t**a/, /a**p**+**t**a/). Each was carried in a different natural-sounding simple sentence. Speakers read speech material on a computer screen positioned approximately 1 meter away from them. Each stimulus was read eight times in a row. A total of 216 tokens were collected for further analysis (3 (Cluster Type) X 8 (Repetition) X 2 (Speech rate) X 6 (speakers)). All subjects read the presented sentences naturally at a given speech rate as instructed (fast or comfortable).

(1) Stimuli list

a. /ciha**ks**aesə ilhe/
'I work for the Jihak company.

b. /əha**kt**apɨn nonsullo heyatoi/
'(You) should give essay responses in the verbal section.'

c. /cəkha**pt**ako hessə/
'(I) said (that it) was appropriate.'

2.2 Data analysis

The vertical tongue dorsum gesture (TD), the vertical tongue tip gesture (TT), and lip aperture (LA) were analyzed. Using an algorithm on the basis of a velocity threshold, we defined three gestural landmarks (gestural onset, constriction onset, and constriction offset) (see a detailed description of the labeling procedure in Son et al., (2007)) using MVIEW (Tiede, 2005).

We measured three articulatory trajectories—the vertical tongue dorsum gesture (TD-y), the vertical tongue tip gesture (TT-y), and lip aperture (LA). In the following are the relevant kinematic measurements of the tongue dorsum gesture, the tongue tip gesture, and the lip aperture gesture. Figure 2 schematically shows the measures for the tongue dorsum gesture. The tongue tip gesture and lip aperture were measured the same way.

(a) Gestural onset (onset of tongue dorsum movement; onset of tongue tip movement; onset of lip movement) (Fig. 2.a).
(b) Constriction onset (target of tongue dorsum closing; target of tongue tip closing; target of lip closing) (Fig. 2.b).
(c) Constriction offset (offset of tongue dorsum opening; offset of tongue tip opening; offset of lip opening) (Fig. 2.c).
(d) Formation duration (duration of tongue dorsum movement; duration of tongue tip movement; duration of lip movement) (Fig. 2.d).
(e) Constriction duration (constriction duration from target of tongue dorsum closing to offset of opening; Constriction duration from target of tongue tip closing to offset of opening; constriction

duration from target of lip closing to offset of opening; (Fig, 2.e).

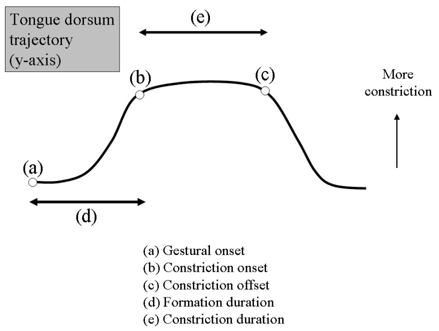

Figure 2. Schematized vertical tongue dorsum movement trajectory.

In comparing gestural overlap in three different phonological contexts, two derived measures were used. First, the onset-to-onset lag were examined. Second, we estimated the percentage of overlap (% OL) for the temporal area shared by C1C2 with the basis for constriction duration of C1 at 100%. For example, if the overlapped portion of the C1C2 sequence maintained the whole constriction duration of C1, we gave a positive 100% OL. Negative % OL indicates that there is a time lag between the constriction offset of C1 and the constriction onset of C2. In Figure 3 are relevant kinematic measurements of the tongue body and the tongue tip (e.g., /k/) which were referred to in Figure 3.

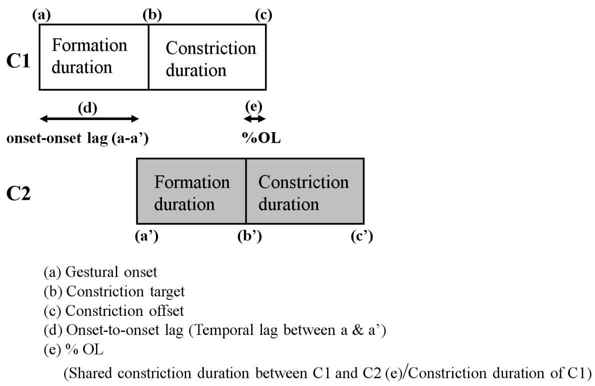

Figure 3. Two schematized gestural overlap measurements (onset-to-onset lag; %OL).

2.3 Statistical analysis

In order to show data representing a language group, repeated measures analyses of variance (RM ANOVA) were conducted in statistical package for the social sciences (SPSS), version 17 (Max & Onghena, 1999). For each subject, each data point corresponds to the mean score of the tongue dorsum gesture, the tongue tip gesture, and lip aperture in different segmental contexts (/ks/, /kt/, /pt/). F-ratios and p-values generated from Huynh-Feldt corrected degrees of freedom and error terms were reported at the significance level of 0.05. (Huynh & Feldt, 1970). The within-subject factors were Cluster type (/ks/, /kt/, and /pt/) and Speech rate (fast and comfortable). Posthoc pairwise comparisons were carried out each time a difference between factors (Cluster type and Speech rate) needed to be determined.

3. Results

Overall, we observed a main effect of Cluster type for % OL ($p<0.005$) and the Onset-to-onset lag ($p<0.005$). There was a main effect of Cluster type for Formation duration ($p<0.05$). However, a main effect of Speech rate was consistently observed for every measure ($p<0.05$) except the Onset-to-onset lag ($p>0.05$). No interaction between Cluster type and Speech rate was detected ($p>0.05$).

3.1 Gestural overlap

3.1.1 Onset-to-onset lag

There was a main effect of Cluster type when examining Onset-to-onset lag in three CC sequences (/ks/>(/kt/=/pt/)). Korean speakers produced less overlap in the stop-fricative with lingual articulations (/ks/). However, /kt/ and /pt/ sequences demonstrated similarity in Onset-to-onset lag ($F[2,10]=15.19$, $p<0.005$). A significant Speech rate effect was not observed ($F[1,5]=1.32$, $p>0.05$) (26.69(2.79) for Fast rate vs. 25.38(3.6) for Comfortable rate) (Fast rate=Comfortable rate). The results are shown in Figure 4.

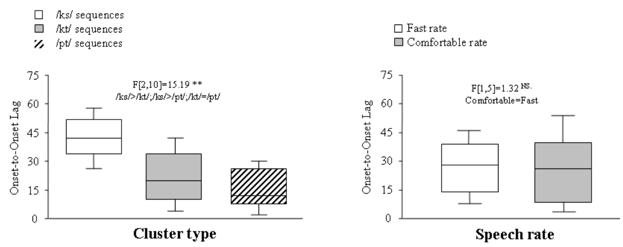

Figure 4. Onset-to-onset lag in C1C2 sequences by Cluster type and by Speech rate (Note that symbols "*" and "**" refer to $p<0.05$ & $p<0.005$, respectively.).

3.1.2 Percentage of overlap (%OL)

Gestural overlap measured as % OL exhibited similar results with a main effect of Cluster type for the Onset-to-onset lag.

Specifically, % OL is greater for the stop-stop sequences (/kt/=/pt/) compared to the stop-fricative sequence (/ks/) (/ks/<[/kt/=/pt/]) ($F[2,10]=14.65$, $p<0.005$). Less overlap was consistently observed only in the stop-fricative sequence with lingual articulations (/ks/). There was also a main effect of Speech rate, showing that a greater % OL (e.g., with greater positive values) is observed in comfortable rate than in fast rate ($F[1,5]=21.54$, $p<0.05$) (Fast rate<Comfortable rate). The results are shown in Figure 5.

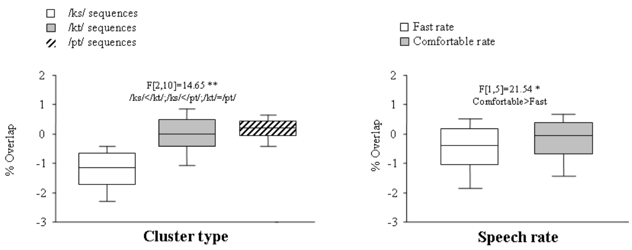

Figure 5. % OL in C1C2 sequences by Cluster type and by Speech rate (Note that symbols "*" and "**" refer to $p<0.05$ & $p<0.005$, respectively.).

3.2 Formation Duration

There was a significant effect of Cluster type for formation duration of C2 ($F[1.8, 8.8]=5.8$, $p<0.05$) (/kt/>(/ks/=/pt/)). There was a main effect of Speech rate, indicating longer duration in comfortable rate than in fast rate (Comfortable>Fast) ($F[1,5]=8.9$, $p<0.05$). The results appear in Figure 6.

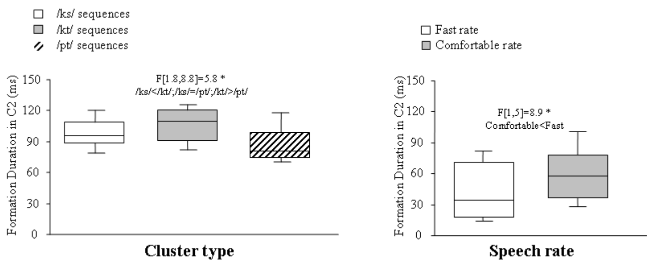

Figure 6. Formation duration by Cluster type and by Speech rate (Note that symbols "*" and "**" refer to $p<0.05$ & $p<0.005$, respectively.).

4. Summary and Discussion

4.1 Summary

In this paper, we examined gestural overlap of three C1C2 sequences (/ks/, /kt/, /pt/), confined to non-assimilation contexts in Korean, analyzing two overlap measures (Onset-to-onset lag and % OL) and formation duration of the tongue tip gesture. When we examined three selected sequences (/ks/, /kt/, /pt/) for Cluster type effects and Speech rate effects, we comprehensively took into account place of articulation (front-to-back vs. back-to-front), manner of articulation (stop-stop vs. stop-fricative), and the articulators involved (lingual vs. nonlingual articulators) in data interpretation.

4.2 Gestural overlap

The results showed that there were no order effects across the board. In Kochetov et al. (2007), a front-to-back sequence (/pt/) showed more overlap than a back-to-front sequence (/kt/, /kp/). They attributed order-dependent gestural overlap to perceptual recoverability (as in Chitoran et al., 2001). In particular, more gestural overlap is mutually accepted between a speaker and a listener if phonetic cues of C1 (gestural release) can occur anytime during C2 articulation. However, less overlap is preferred if phonetic cues are not transferred from a speaker to a listener when phonetic cues of C1 are obscured by C2 articulation. As an alternative account Kocheove et al. (2008) also attributed difference in degree of gestural overlap to low-level motor constraint such that two consecutive lingual sequences (e.g., /kt/, the tongue body and the tongue tip in this case) mutually restrain each other and result in less overlap. However, the results of the current study showed that gestural overlap in two measures (Onset-to-onset lag and % OL) was sensitive to different manner of articulation. The results observed in the non-assimilating contexts showed a language-specific gestural pattern, which was also true for Korean assimilating contexts as examined in Son (2008) (e,g., /tk/=/pk/).

The similarity in degree of gestural overlap in /kt/ (back-to-front; lingual-lingual) and /pt/ (front-to-back; nonlingual-lingual) observed in this study has no basis in order effects or physiological motor constraints on lingual articulators. This contradicts findings from other languages such as Georgian (Chitoran et al., 2002) with order effects and French (Kühnert et al., 2006) with order effects and low-level physiological motor constraints. However, for non-assimilating contexts in Korean, it was confirmed that degree of overlap is a function of assimilation context effects (/pk/ (assimilation context, more gestural overlap) vs. /pt/ (non-assimilation context, less gestural overlap) – not of order effects or physiologically determined motor constraints. The current finding of similarity in degree of overlap in non-assimilating contexts (/kt/=/pt/) confirmed that gestural overlap varies as a function of assimilation context effects in Korean (Son, 2008; Son et al., 2007).

Note that a back-to-front sequence with lingual articulations (/ks/) showed less overlap than /kt/ and /pt/. With a different manner of articulation in C2, the /ks/ sequence had no basis for less overlap in either order effects and physiological constraints on lingual movement. To account for this, we suspect that the jaw articulator plays a role in gestural overlap. A previous study has shown that jaw height varied in the order (coronal>labial>dorsal), which served to help the relevant active articulators (Keating et al., 1994). However, Mooshammer et al. (2006) suggested that the jaw articulator is as well has an active, not just passive and minor role, in the fricative /s/. To quote Mooshammer et al. (2006:146), "··· here the lower incisors serve as a second noise source and therefore the jaw position is controlled actively to provide a small distance between the upper and lower incisors for the generation of salient high frequency frication." Given the special status of the fricative /s/ with higher jaw position, it is plausible that two articulators which have a greater gap in jaw height would demonstrate less gestural overlap.

Jaw height is another instance of low-level physiological motor constraints at work (Gao, Mooshammer, Hagedorn, Nam, Tiede, Chang, Hsieh, & Goldstein, 2011). A language-specific behavior in gestural overlap was observed in their cross-linguistic study. In Taiwanese, /pt/ showed synchronous coordination between two gestures (more overlap), which was attributed to the shared jaw articulator. On the other hand, /pk/ showed less overlap. The low-level physiological motor constraint did not play a role in the comparison between /pt/ and /pk/ in American English as the authors attributed difference in degree of gestural overlap (/pt/>pk) to language-specificity.

In this paper, we observed that gestural overlap should be more comprehensively studied to include different manners of articulation. Although we did not find substantial evidence for physiological constraints on lingual articulation or order contrast, we observed that gestural overlap varied with reference to low-level physiological motor constraints on jaw height. To sum up, gestural overlap in Korean non-assimilating contexts patterned with Taiwanese, but not with Georgian or French.

In the current study, we partially replicated Kochetov et al. (2007)'s cross-linguistic study when comparing /kt/ (back-to-front; lingual-lingual articulations) to /pt/ (front-to-back; labial-lingual articulations). The results of this study differed from Kochetov et al.'s (2007) in that no difference was found here in gestural overlap. Although we cannot pinpoint what could have led to this contrast in the two studies for the time being, this study took advantage of a larger pool of speakers (3 (Kochetov et al., 2007) vs. 6 (current study)), which can better represent Korean language pattern in particular. The conflicting results concerning gestural overlap remain for future studies to resolve.

4.3 Formation duration

In this study, we confined our scope of study to formation duration of C2 in three selected sequences: /ks/ contrasted to /kt/ with a different manner of articulation in C2, and /kt/ contrasted to /pt/ with a different place of articulation in C1. The result showed that the tongue tip gesture for /t/ in C2 demonstrated longer formation duration than /s/ only if /t/ is preceded by another lingual segment (/kt/>(/ks/=/pt/)). This is not the case with French (Kühnert et al., 2006), which showed longer formation duration of a coronal (/n/, /l/) after a labial consonant (/p/, /f/). Kühnert et al. (2006) determined that longer formation duration of a coronal /t/ preceded by a labial consonant was attributed to its relatively free articulation during /p/. Under the low-level physiological motor constraint account by Kühnert et al. (2006), Korean was expected to have a similar result. However, we observed exactly the opposite pattern; /t/ with a preceding velar stop /k/ exhibited longer formation duration (/k**t**/>/p**t**/). This is another instance of language-specificity, distinct from the case in French (Kühnert et al., 2006).

5. Conclusion

In this paper, we have examined three selected sequences in Korean non-assimilating contexts (/ks/, /kt/, /pt/). We have particularly focused on gestual overlap and formation duration of coronals. The results showed some language-particular articulatory characteristics of inter-consonantal coordination. The onset-to-onset lags of /kt/ and /pt/ sequences were significantly shorter than that of /ks/. Likewise, %OL was greater in /kt/ and /pt/ than in /ks/. This indicated that a pair of successive lingual gestures did not always constrain each other; gestural overlap in /ks/ (i.e., longer lag and less overlap) was distinguished from that in /kt/ (i.e., shorter lag and more overlap) and the latter in turn showed a pattern similar to heterorganic /pt/ (/ks/</kt/ and /pt/). Inter-gestural coordination was affected by C1 (place of articulation) as

well as C2 (manner of articulation), the former occurring with reference to a speech motor constraint on lingual articulators. A distinctive pattern in gestural overlap of different C1C2 sequences (velar-fricative<velar-stop) also occurred with reference to a speech motor constraint on the jaw articulator. Speech rate effects were only observed in one overlap measure (% OL) (Fast<Comfortable). Formation duration was also sensitive to Speech rate effects (Fast<Comfortable). In contrast, a study of formation duration showed that a coronal stop (/t/) in C2 following a velar stop (/k/) is longer than both i) /t/ in C2 with /p/ in C1 and /s/ in C2 with /k/ in C1. That is, coronals exhibited distinctive formation duration only when in the form of a stop (and not its fricative counterpart) (manner of articulation) and a coronal stop (/t/) in C2 can vary in movement duration as a function of difference in segments appearing in C1 (/p/ (labial) vs. /k/ (dorsal) in this case).

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References

Browman, C., & Goldstein, L. (1989). “Articulatory gestures as phonological units”, *Phonology*, Vol. 6, pp. 201-251.

Browman, C., & Goldstein, L. (1992). “Articulatory phonology: An overview”, *Phonetica*, Vol. 49, pp. 155-180.

Chitoran, I., Goldstein, L., & Byrd, D. (2002). “estural overlap and recoverability: Articulatory evidence from Georgian”, in C. Gussenhoven & N. Warner (Eds.), *Laboratory Phonology* VII, Mouton de Gruyter (pp. 419-448).

Gao, M., Mooshammer, T., Hagedorn, C., Nam, H., Tiede, M., Chang, Y., Hsieh, F, & Goldstein, M. (to appear). “Intra- and inter-syllabic coordination: An articulatory study of Taiwanese and English”, *Proceedings of the 17th International Congress of Phonetic Sciences*.

Huynh, H., & Feldt, L. S. (1970). “Conditions under which mean square ratios in repeated measurements designs have exact F-distributions”, *Journal of the American Statistical Association*, Vol. 65, pp. 1582-1589.

Kochetov, A., & Pouplier, M. (2008). “Phonetic variability and grammatical knowledge: An articulatory study of Korean place assimilation”, *Phonology*, Vol. 25, pp. 1-33.

Kochetov, A., & Pouplier, M., & Son, M. (2007). “Cross-langauge differences in overlap and assimilation patterns in Korean and Russian”, P*roceedings of the 16 International Congress of Phonetic Sciences*, pp. 1361-1364.

Kühnert, B., Hoole, P., & Mooshammer, T. (2006). “Gestural overlap and C-center in selected French consonant clusters”, *Proceedings of the 7th International Seminar of Speech Production*, pp.327-334.

Max, L., & Onghena, P. (1999). “Some issues in the statistical analysis of completely randomized and repeated measures designs for speech, languages, and hearing research”, *Journal of Speech, Langauge, and Hearing Research*, Vol. 42, pp. 261-270.

Mooshammer, T., Hoole, P., & Geumann, A. (2006). “Jaw and order”, *Language & Speech*, Vol. 50, pp. 145-176.

Nam, H. (2007). “Syllable level intergestural timing model: Split-gesture dynamics focusing on positional asymmetry and moraic structure”, in J. Cole and J. I. Hualde (Eds.), *Papers in Laboratory Phonology* IX, Mouton de Gruyter, (pp. 483 - 506).

Perkell, J., Cohen, M., Svirsky, M., Matthies, M., Garabieta, I., & Jackson, M. (1992). “Electromagnetic madsagittal articulometer (EMMA) systems for transducing speech articulatory movements”, *Journal of the Acoustical Society of America*, Vol. 92, pp. 3078-3096.

Son, M. (2008). “Gestural overlap as a function of assimilation contrast”, *Korean Journal of Linguistics* 33. pp. 665-691.

Son, M., Kochetov, A., & Pouplier, M. (2008). “The role of gestural overlap in perceptual place assimilation: Evidence from Korean”, in C. Jennifer & I. Hualde (Eds.), *Laboratory Phonology* IX. (pp. 507-534).

Steriade, D. (1997). “Phonetics in phonology: The case of laryngeal neutralization”, Ms. Massachusetts Institute of Technology.

Tiede, M. (2005). “MVIEW: Software for visualization and analysis of concurrently recorded movement data”. Hanskins Laboratory.

Westbury, J.R. (1994). “On coordinate systems and the representation of articulatory movements”, *Journal of the Acoustical Society of America*, Vol. 95, pp. 2271-2273.

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