DISAPPEARING SUPRALARYNGEAL ARTICULATORY DISTINCTION OF THE THREE-WAY LARYNGEAL CONTRAST OF KOREAN VELAR STOPS

Jiyeon Song[1], Sahyang Kim[2], Taehong Cho[1]

[1]Hanyang Institute for Phonetics and Cognitive Sciences of Language (HIPCS), Hanyang University
[2]Hongik University
jiyeoni00@hanyang.ac.kr, sahyang@hongik.ac.kr, tcho@hanyang.ac.kr

ABSTRACT

This EMA study investigated articulatory characteristics of the three-way contrast of Korean velar stops in CV contexts. Building on a previous small-scaled study that indicated a three-way kinematic distinction of bilabials, the current study examined velars with 22 speakers to further explore the kinematic evidence of the three-way stop contrast, by considering the recent VOT merger between the lenis and aspirated stops. The results showed that both males and females maintained the aspirated-lenis distinction only minimally in different kinematic dimensions. Males showed a three-way contrast in peak velocity of C-to-V opening movement (/k^h/</k/</k*/) with a lenis-aspirated distinction. Females never showed a three-way contrast in any kinematic measure, but a two-way lenis-aspirated distinction only in C-to-V deceleration duration (/k*/=/k^h/</k/). It appears that the lenis-aspirated kinematic distinction is being attenuated, led by female speakers, in line with the loss of lenis-aspirated distinction in VOT, which would otherwise contribute to the supralaryngeal articulation.

Keywords: Korean three-way stop contrast, VOT merger, sound change, kinematic characteristics

1. INTRODUCTION

In many languages, stops are mostly classified based on voicing and aspiration. However, Korean shows an unusual three-way contrast of stops that are all voiceless word-initially. The three-way contrastive stops are often called the lenis, the fortis, and the aspirated stops and occur at three places of articulation (bilabial, denti-alveolar, and velar). In general, these stops are assumed to be contrastive in laryngeal terms: the lenis stops are characterized as breathy, and slightly aspirated; the fortis stops as tensed, laryngealized, and unaspirated, and the aspirated stops as strongly aspirated (e.g., [6]). It was also previously suggested that the three-way contrast can be explained with VOT alone (see [6] for related discussion) which could be defined as the timing between the supralaryngeal release gesture and the laryngeal voicing gesture (cf. [12]). (Note, however, that the classification of stops is traditionally defined along two phonetic dimensions: voicing and aspiration (e.g., [13]). Traditionally, the three-way contrast was considered to be reflected in the mean VOTs, which would be longest for the aspirated, shortest for the fortis, and intermediate for the lenis stops, although VOT ranges may overlap quite substantially between the lenis and the aspirated stops (cf. [4, 6]). Subsequent studies, however, showed that the distinction in VOT between lenis and aspirated stops has been neutralized, showing a VOT merger between the two stop categories (e.g., [1, 8, 11, 17]). Further, it has been suggested that females are more likely to show the VOT merger than males in Seoul Korean (e.g., [9]).

Aerodynamic and physiological factors involved in determining VOT differences are related to articulatory movement velocity and a temporal adjustment between stop closure duration and VOT ([5]). According to [14], there is a trade-off between the closure duration and the following VOT within the constant duration of abduction and adduction cycle of the vocal cords. In other words, the longer the closure duration, the shorter the VOT. Therefore, fortis consonants with the shortest VOT have the longest closure duration. This was partially supported in the previous research in kinematic terms with the fortis having the longest closure duration by a binary distinction (/p/</p^h p*/) in lip constriction duration in the articulatory phonology research about Korean labial stops (e.g., [7]) and the three-way contrast in the tongue dorsum closure duration (/k/</k^h/</k*/) (e.g., [3]).

Brunner et al. [3] found the three-way contrast in kinematic terms in peak velocity of the tongue dorsum closing movement (/k/</k^h/</k*/). In a similar vein, a kinematic study of labials by [7] found a three-way contrast in lip constriction degree (/p/</p^h/</p*) at the constriction offset in both IP-initial and IP-medial positions, suggesting that the three-way contrast becomes greater as the constriction progresses. Brunner et al. [3] also showed the three-way contrast in deceleration duration of the tongue dorsum closure movement (/k*/</k^h/</k/). This is in line with the perspective of the virtual target hypothesis in which different target positions could be defined virtually even beyond the

physical limit of the palate, leading to different closure durations.

These kinematic studies taken together indicate that the three-way stop contrast in Korean, although they may be defined primarily in laryngeal terms, can still be distinctive at the supralaryngeal level as reflected in kinematic measures. But these studies were based on a small number of speakers (three speakers for [3], five speakers for [7]), and therefore it would be difficult to generalize the findings. Moreover, recent studies, as introduced above, indicate that there has been a VOT merger between the lenis and the aspirated stop whose distinction is now made by F0 at least among younger speakers of Seoul Korean. Given that those kinematic studies were carried out several years ago and the sound change of the VOT merger appears to have been in progress, an important question arises as to whether and how the kinematic properties of the three-way stop contrast may have also been modified, reflecting possible effects of the sound change that might have impacted supralaryngeal articulation. In particular, if we define VOT articulatorily (as in [5]), it is possible that the tongue posture associated with VOT may vary depending on how long the hold (closure) duration continues, which tends to be inversely related to VOT (cf. [14]). However, it is possible that due to the VOT merger, the lenis-aspirated distinction would no longer be associated with the differential hold duration-related impacts on articulation. If so, the supralaryngeal differences between the lenis and the aspirated stops that previously existed may now have disappeared along with the VOT merger.

With these possibilities in mind, the present study examines production of monosyllable words of 22 young Seoul Korean speakers to explore how the three-way laryngeal contrast of velars is realized kinematically at the supralaryngeal level, and how the results may be interpreted in connection with the recent VOT merger between the lenis and aspirated stops. Given that the on-going sound change is assumed to be led by female speakers, it will also be considered whether any loss of supralaryngeal distinction especially between the lenis and the aspirated may be more evident in the female than in the male speech.

2. METHODS

2.1. Participants and Procedure

Twenty-two Seoul Gyeonggi speakers participated in the experiment as part of a large-scale acoustic-articulatory database building project in Korean at Hanyang Institute for Phonetics and Cognitive Science of Language [18]. Each participant was asked to produce a sequence of eighteen syllables of the form /Ca/ of which the three-way contrastive velar stops (/ka/, /k^{h}a/, /k*a/) were analyzed for the current study. A total of 132 tokens (3 velars x 22 speakers x 2 repetition) are reported in this paper.

The articulatory data were collected using the 3D electromagnetic articulography (EMA, AG501, Carstens Electronics). Eight movement sensors were used to track the movement of articulators. Six sensors were attached to the articulators: tongue dorsum (TD), tongue body, tongue tip, the lower lip and upper lips at the vermilion borders, and the middle of the lower gumline. Two fixed reference sensors were attached to the nasion and upper incisor. The data of TD sensor has been analyzed to track the closing and opening movement of TD.

2.2. Measurements and Statistical analysis

Mview (a set of Matlab scripts developed by Mark Tiede at Haskins Labs) was used to analyze the obtained kinematic data. Figure 1 shows a schematic of the kinematic measures and relevant landmarks for the closing and opening movement trajectory of the tongue dorsum, and the tangential velocity of the tongue dorsum.

Kinematic measurements of the tongue dorsum in accordance with the labels of Figure 1 include the following: (a) Closing Movement Duration , (a-1) Acceleration Duration 1: duration from Onset 1 to Peak Velocity 1, (a-2) Deceleration Duration 1: from Peak Velocity 1 to Target 1, (a-3) Peak Velocity 1, (b) Opening Movement Duration, (b-1) Acceleration Duration 2: from Onset 2 to Peak Velocity 2, (b-2) Deceleration Duration 2: from Peak Velocity 2 to Target 2, (b-3) Peak Velocity 2, (c) Closure Duration: from Target 1 to Onset 2. Forward and vertical movements duration from Onset 1 to Target 1 were also measured.

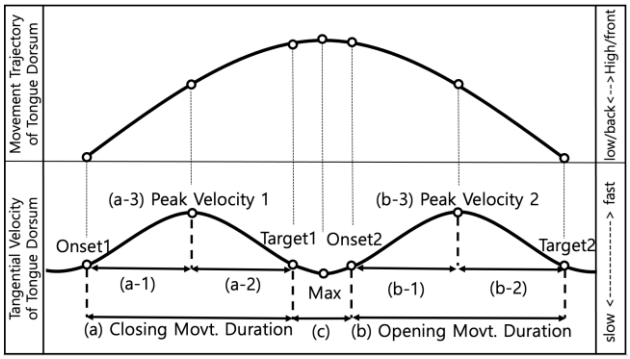

Figure 1. Schematized tongue dorsum movement trajectory measures and tangential velocity

Linear mixed-effects models (LMMs)[1] were created with the *lme4* package ([2]), followed by the post-hoc Tukey's pairwise comparisons via the

emmeans package ([16]) in R ([15]). *Gender* (male and female) and *Consonant* (lenis, aspirated and fortis) were employed as fixed factors and *Speaker* as a random effect. Given that the gender-related difference is a crucial aspect of our research question, we performed post-hoc Tukey tests with Tukey correction to examine the *Consonant* effect separately for male and female groups. We carried out these tests even in the absence of significant interactions found in the initial linear-mixed effects models to ensure a complete analysis.

3. RESULTS

Results of LMMs show that there were no significant effects either of *Consonant* or of *Gender* on the acceleration and deceleration duration and peak velocity in the closing movement, but significant effects were obtained on the peak velocity and deceleration duration in the opening movement, the opening movement duration, and closure duration. Their mean values and the standard deviations are given in Table 1.

Table 1. Mean values and the standard deviations in parentheses of Closure Duration, Peak Velocity 2, Deceleration Duration 2, and Opening Movement Duration

	Closure Duration (ms)			Peak Velocity 2 (cm/sec)		
	k	k^h	k^*	k	k^h	k^*
Female	63.7 (43.9)	68.3 (35.1)	108 (78.3)	13.1 (2.67)	12.0 (1.93)	14.6 (3.30)
Male	61.3 (29.3)	71.6 (34.3)	94.6 (46.0)	17.7 (4.97)	15.7 (3.35)	20.7 (4.91)
	Deceleration Duration 2 (ms)			**Opening Movt. Duration (ms)**		
	k	k^h	k^*	k	k^h	k^*
Female	94.6 (30.4)	74.3 (23.4)	73.4 (29.3)	160 (39.6)	142 (27.2)	138 (34.5)
Male	85.3 (21.7)	76.2 (22.9)	54.8 (22.6)	151 (37.3)	150 (42.8)	114 (22.4)

Closure Duration showed a significant effect of *Consonant* (β=39.57, SE=11.06, p<0.001), indicating that the fortis stop had a longer closure duration than the aspirated stop. There was no significant effect of *Gender*, and no interaction between *Consonant* and *Gender*. However, separate analyses of *Consonant* effects across genders revealed some gender-related differences. Post-hoc comparisons, with Tukey correction, of the three velar stops for Closure Duration suggested that, for females, the fortis stop had a significantly longer closure duration than the lenis stop (β=44.1, SE=10.9, p<0.001) and the aspirated stop (β=-39.6, SE=15.8, p<0.05). However, there was no significant difference between the aspirated and lenis stops (/k/, /k^h/</k*/). For males, the fortis stop displayed a significantly longer duration than the lenis stop (β=-33.3, SE=10.9, p<0.01), but there was no significant difference between the lenis and aspirated stops, nor between the aspirated and fortis stops (/k/</k*/).

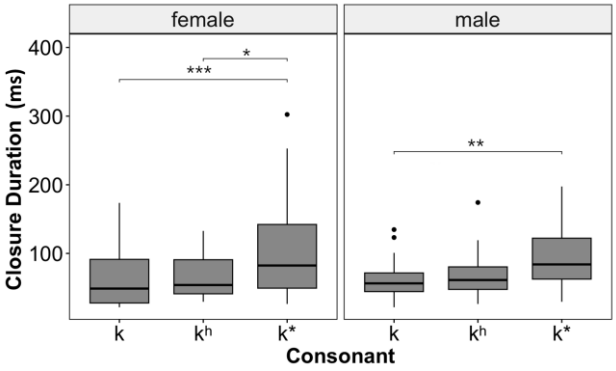

Figure 2. Closure Duration for different stop categories. Error bars indicate standard errors.

Peak Velocity 2 of the opening movement shows main effects of *Consonant* (β=2.67 SE= 0.76, p<0.001) and *Gender* (β= 3.73, SE= 1.40, p<0.05). There was also an interaction between *Consonant* and *Gender* (β=2.39, SE=1.08, p<0.05). Follow-up post-hoc comparisons (with Tukey correction) of the three velar stops for Peak Velocity 2 of the opening movement showed that for *females*, the fortis stop had significantly faster peak velocity than the aspirated stop (β =-2.67, SE=0.87, p<0.01), but there was no significant difference between the lenis and aspirated stops, nor between the lenis and fortis stops (/k^h/</k*/). For *males*, the three velar stops were presented with significantly different peak velocities of the opening movement (lenis and aspirated: β =-2.01, SE=0.73, p<0.05; aspirated and fortis: β =-5.06, SE=0.87, p<0.001; lenis and fortis: β =3.05, SE=0.95, p<0.01) in the following order: /k^h/</k/</k*/.

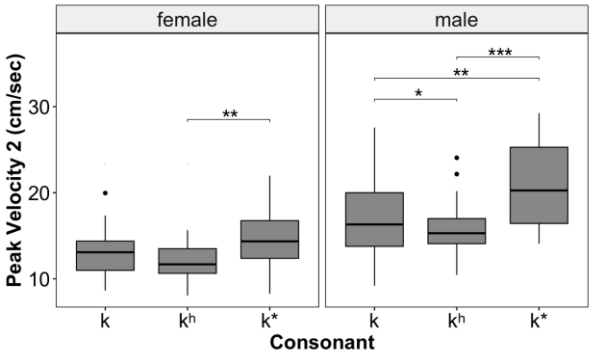

Figure 3. Peak velocity 2 for different stop categories. Error bars indicate standard errors.

Deceleration Duration 2 of the opening movement shows main effects of *Consonant* (β =20.28, SE=6.36, p<0.01), but there was no significant effect of *Gender*. There was an interaction between *Consonant* and

Gender (β=-20, SE=8.99, p<0.05). Post-hoc comparisons (with Tukey correction) of the three velars for the deceleration duration of the opening movement indicated that for *females*, the lenis stop showed significantly longer deceleration duration than the aspirated stop (β=-20.3, SE=6.95, p<0.01) and the fortis stop (β=-21.2, SE=6.2, p<0.01), but there was no significant difference between the aspirated and fortis showing the following order: /k^h/, /k*/</k/. For *males*, the fortis stop was presented with the shorter deceleration duration of the opening movement than the lenis (β=-30.5, SE=6.2, p<0.001) and aspirated stops (β=21.42, SE= 6.35, p<0.01) (/k/, /k^h/</k*/).

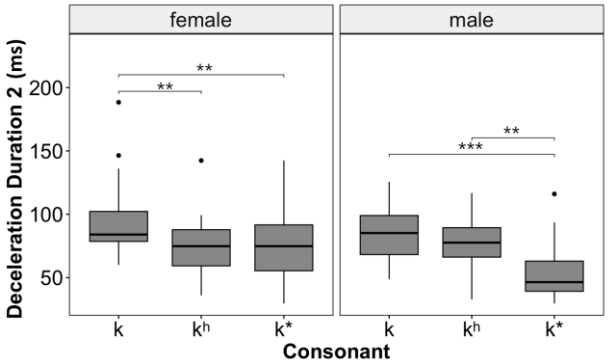

Figure 4. Deceleration Duration 2 of the opening movement for different stop categories. Error bars indicate standard errors.

Opening Movement Duration shows no main effects of *Consonant* and *Gender*. Nonetheless, a trend effect of *Consonant* was observed (β=17.66, SE=9.12, p=0.056). The interaction effect of *Consonant* and *Gender* was significant (β=-31.48, SE= 12.90, p< 0.05).

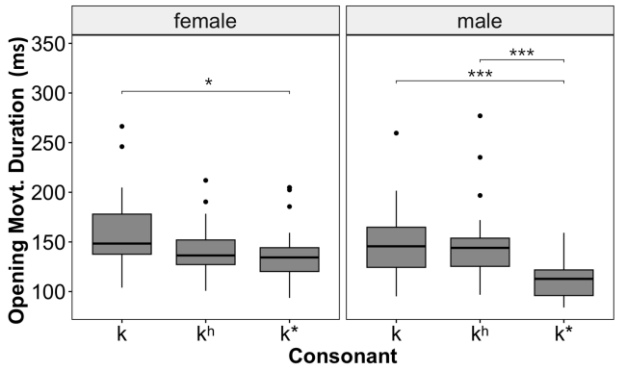

Figure 5. Opening Movement Duration for different stop categories. Error bars indicate standard errors.

Post-hoc comparisons (with Tukey correction) of the three velar stops for the movement duration of the opening movement indicated that for *females*, the fortis had a significantly shorter opening movement duration than the lenis stop (β=-21.6, SE=8.69, p< 0.05) (/k^*/</k/). For *males*, the fortis stop had a significantly shorter opening movement duration than the lenis stop (β=-36.7, SE=8.69, p< 0.001) and the aspirated stop (β=35.39, SE=8.68, p< 0.001) in the following order: /k*/</k/, /k^h/.

Forward movements of TD did not show significant differences between the consonants but there was a significant difference between genders showing more forward movement in *males* than in *females* (β: 3.10, SE= 0.53, p<0.001). There was no significant result in vertical movements, either, showing no effect of *Consonant* or *Gender*.

4. SUMMARY AND CONCLUSION

The results from Closure Duration showed no three-way contrast for either females or males: females showed a binary contrast (/k/=/k^h/</k*/) while males showed a difference only between the lenis and fortis stops (/k/</k*/). For Peak Velocity 2, males showed the three-way contrast (/k^h/</k/</k*/) while females show the difference only between the aspirated and fortis (/k^h/</k*/). As for Deceleration Duration 2 of the opening movement, females showed the binary contrast with no evidence of the aspirated and fortis distinction (/k^h/=/k*/</k/) while males showed a binary distinction with no contrast between the lenis and aspirated (/k/=/k^h/</k*/). The results from Opening Movement Duration indicated that females showed a distinction only between the lenis and fortis stops (/k^*/</k/) whereas males displayed the binary distinction without a contrast of the lenis and aspirated (/k*/</k/=/k^h/). However, there was no significant result between the three consonants in the vertical and forward movements.

Turning to the results of closure duration, the results appear to illustrate a trade-off between closure duration and the following VOT, such that fortis stops with the shortest VOT are presented with the longest closure duration. However, there was no distinction for the closure duration between the lenis and aspirated stops. This may imply that neutralized closure duration is caused by the loss of lenis-aspirated distinction in VOT, and thereby there were no hold duration-related differential impacts on supralaryngeal articulation between the lenis and aspirated stops. Another interesting finding is that a three-way contrast still remained for Peak Velocity 2 of the opening movement in males in the reverse order of the traditional three-way VOT contrast (/k^h/</k/</k*/), but females did not show the same three-way distinction. This may suggest that males are more conservative than females when it comes to the on-going sound change of laryngeal contrast even in supralaryngeal articulation.

It is worth noting that the results of the present study did not show any differences in kinematic measures associated with the consonantal closing movement in CV consonants, despite previous findings by [3] that reported consonantal effects on the closing movement kinematics in VCV contexts. This discrepancy may be due to the time gap between the two studies or the difference in syllable structure, or a combination of both factors.

With these findings taken together suggest the current study offers some evidence of disappearing supralaryngeal articulatory distinction of the three-way stop contrast in velars along with the on-going sound change related to the VOT merger. Further, the results also support the view that the lenis-aspirated kinematic distinction is disappearing and led by female speakers. However, our results must be taken with caution and cannot be fully generalized because the current study was based on stops in monosyllable words produced in isolation. Therefore, it remains to be seen how our findings can be generalized as more data become available.

5. ACKNOWLEDGEMENT

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2021S1A5C2A02086884).

6. REFERENCES

[1] Bang, H. Y., Sonderegger, M., Kang, Y., Clayards, M., & Yoon, T. J. 2018. The emergence, progress, and impact of sound change in progress in Seoul Korean: Implications for mechanisms of tonogenesis. *Journal of Phonetics*, *66*, 120-144.

[2] Bates, D., Mächler, M., Bolker, B., & Walker, S. 2015. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67(1), 1-48.

[3] Brunner, J., Fuchs, S., & Perrier, P. 2011. Supralaryngeal control in Korean velar stops. *Journal of Phonetics*, *39*(2), 178-195.

[4] Cho, T. 1996. Vowel correlates to consonant phonation: an acoustic-perceptual study of Korean obstruents. MA thesis, University of Texas at Arlington.

[5] Cho, T., & Ladefoged, P. 1999. Variation and universals in VOT: evidence from 18 languages. *Journal of phonetics*, *27*(2), 207-229.

[6] Cho, T., Jun, S. A., & Ladefoged, P. 2002. Acoustic and aerodynamic correlates of Korean stops and fricatives. *Journal of phonetics*, 30(2), 193-228.

[7] Cho, T., Son, M., & Kim, S. 2016. Articulatory reflexes of the three-way contrast in labial stops and kinematic evidence for domain-initial strengthening in Korean. *Journal of the International Phonetic Association*, *46*(2), 129-155.

[8] Choi, J., Kim, S., & Cho, T. 2020. An apparent-time study of an ongoing sound changes in Seoul Korean: A prosodic account. *Plos one*, *15*(10).

[9] Kang, Y. 2014. Voice Onset Time merger and development of tonal contrast in Seoul Korean stops: A corpus study. Journal of Phonetics, 45, 76-90.

[10] Kim, H., Maeda, S., & Honda, K. 2010. Invariant articulatory bases of the features [tense] and [spread glottis] in Korean plosives: New stroboscopic cine-MRI data. *Journal of Phonetics*, *38*(1), 90-108.

[11] Kim, M. R. 2013. Interspeaker variation on VOT merger and shortening in Seoul Korean. In *Proceedings of Meetings on Acoustics ICA2013* (Vol. 19, No. 1, p. 060212). Acoustical Society of America.

[12] Ladefoged, P., & Cho, T. 2001. Linking linguistic contrasts to reality: The case of VOT. *TravauxDu CercleLinguistiqueDe Copenhague*, *31*.

[13] Lisker, L., & Abramson, A. S. 1964. A cross-language study of voicing in initial stops: Acoustical measurements. Word, 20(3), 384-422.

[14] Maddieson, I. 1997. Phonetic Universals. In 1he handbook of phonetic sciences (J. Laver & W. J. Hardcastle, editors), pp. 619-639. Oxford: Blackwells.

[15] R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

[16] Russell V. Lenth, 2022. emmeans: Estimated Marginal Means, aka Least-Squares Means. R package version 1.7.5.

[17] Silva, D. J. 2006. Acoustic evidence for the emergence of tonal contrast in contemporary Korean. *Phonology*, *23*(2), 287-308.

[18] The Hanyang Institute for Phonetics and Cognitive Sciences of Language (HIPCS). 2022, Dynamics of Speech Production through Articulatory DB Construction.

[1] Full models

(i) ClosureDuration~gender*consonant+(1|speaker)

(ii) PeakVelocity2~gender*consonant+(1+gender | speaker)

(iii) DecelerationDuration2~gender*consonant+(1+gender |speaker)

(iv) OpeningMovementDuration~gender*consonant+(1+gender | speaker)