

# KOREAN MOTHERS' PRODUCTION OF LARYNGEAL STOPS TO THEIR INFANTS AS COMPARED WITH ADULTS IN THE CONTEXT OF TONOGENESIS

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## ABSTRACT

Korean stops have undergone a tonogenetic sound change whereby the reduced voice onset time (VOT) differences between aspirated and lenis stops have been replaced by the enhanced fundamental frequency (F0) distinction. Yet, the actual distributions of various cues available in the input to young infants have not been well documented. The present study examined acoustic characteristics of 33 Korean mothers' production of three-way laryngeal stops in infant-directed and adult-directed speech.

On average, Korean mothers today represent the generation that has already gone through tonogenesis – aspirated and lenis stops were distinguished with F0, not with VOT. Yet, individual mothers varied widely; with some mothers clearly showing tonogenetic changes while others are still producing traditional cue patterns. We will discuss the possibility that this on-going shift in the use of cues for these stops may contribute to a delay in Korean infants' ability to discriminate lenis and aspirated stops.

**Keywords:** tonogenesis, Korean, diachronic change, IDS, ADS

## 1. INTRODUCTION

In the past few decades, Korean has undergone a diachronic change, with this change mainly occurring in Seoul Korean followed by other dialects [1]. The change is a tonogenetic one specific to the pair between the lenis and aspirated stop because the pair used to be distinguished mainly by the VOT difference but the difference has been reduced and F0 difference has been enhanced in its place [2, 3, 4, 5]. The pattern of this tonogenetic change and its potential cause have been relatively well documented in recent years, showing that the change has been driven mostly by female speakers of younger generations born after 1970s [2, 3, 5] and that the high frequency words have driven these effects [6].

However, little is known about the input characteristics to young Korean-learning infants with regard to this diachronic change. Although it has been reported that the tonogenetic change in Seoul Korean

is mostly complete [1], mothers might still present both the primary and secondary cues for distinction in an exaggerated manner when they speak to their young infants, unlike their speech to other adults. Or it is possible that the tonogenetic change has taken its place regardless of the context such that the mothers speak in the same manner whether they speak to young learners or other adults.

There has been one report on the characteristics of cue distribution in infant-directed speech (IDS) as compared with adult-directed speech (ADS) in Korean [7]. When the distribution of VOT and F0 was examined from the recordings of 36 mother-infant interactions (3 age groups of infants, 0, 1, & 2 years of age) under natural free play setting, VOT difference between lenis and aspirated pair was larger in IDS than ADS for all three age groups whereas F0 enhancement was only observed in IDS to 2-year-olds [7]. Furthermore, the VOT difference was not much different between fortis and lenis for IDS compared with ADS. This suggested that mothers tended to modulate the VOT cue even for the stop pair that has undergone the tonogenetic sound change when their infants are younger than 2 years. However, it was already several years ago when the data reported in this paper was collected, and it is possible that the shift has proceeded even further. Considering the speed in which tonogenesis seems to be progressing, additional documentation in similar context (i.e., IDS) a few years apart could provide valuable insight into this historical shift in Korean language.

Furthermore, according to a recent study [4], Korean-learning infants have difficulty with discriminating lenis from aspirated stops until about 10-12 months of age, showing quite a delayed development of perception for this pair. The VOT differences between the two stops were clear in the sound stimuli presented to these infants and yet, the infants younger than 10 months of age did not appear to be able to utilize the VOT cue differences in their discrimination. However, even 4-6-month-olds were successful in utilizing the VOT cue in distinguishing aspirated from fortis stops, the pair that has not been affected by the tonogenetic sound change [6]. This

**Table 1:** Korean words used in the production task.

Korean	IPA	Place	Category
투	tu	Alveolar	Lenis
뚜	t* <sub>u</sub>	Alveolar	Fortis
투	t <sup>h</sup> u	Alveolar	Aspirated
구	ku	Velar	Lenis
꾸	k* <sub>u</sub>	Velar	Fortis
쿠	k <sup>h</sup> u	Velar	Aspirated
부	Pu	Labial	Lenis
뿌	p* <sub>u</sub>	Labial	Fortis
푸	p <sup>h</sup> u	Labial	Aspirated

pattern of Korean infants' development of three-way stop perception suggested a likelihood that their development is partly affected by the shift in the cue use and mixed nature of cue distribution in their input in IDS, ADS, and other speakers' speech (e.g., grand parents' use of these cues).

The present study examined how current Korean mothers produce laryngeal stops in the context of tonogenesis when they speak to the infants as compared with their speech to other adults. If the shift in the cue use has been on-going so that the characteristics might have shifted even more since the report made by [7], we might observe more shift in the cue distribution in IDS compared with the one reported earlier. Additionally, we attempted to examine individual mothers' pattern of change in the cue use. No studies thus far have looked at to what extent an individual speaker reflects the diachronic change in their speech, especially when they modulate their cues depending on the listeners' characteristics.

## 2. DATA & METHODS

### 2.1. Participants

We recorded the laryngeal stops produced by 33 mothers whose age ranged from 25 to 40 years (mean = 32.2 years) but their infants were all 7 to 9 months olds. Among these, 24 mothers grew up and currently reside in Seoul, 5 mothers grew up in GyungSang regions, and 4 mothers grew up in other provinces (such as Jeolla ( $n=2$ ), Gangwon ( $n=1$ ), ChungCheong ( $n=1$ )) but has lived in Seoul during their adulthood.

### 2.2. Procedure

The mothers were taken into a small, sound-treated room. They were then provided with a set of target words. The target words used for recordings were chosen to elicit the nine Korean stops (aspirated, lenis, and fortis stops at three places of articulation). A total of 9 target words had an initial CV syllable, where the

onset C was one of the nine Korean stops, and V was the vowel /u/ (see table 1). All selected target words were pseudowords.

Mothers were instructed to repeat each word five times in ADS and IDS (i.e., speaking to their infants). To ensure that the target words were produced in the same prosodic context in both speaking styles, the mothers produced each target word in a carrier sentence as below:

- 1.1. ADS: ik<sub>AS</sub>in (target word) lako hapnita.
- 1.2. IDS: ik<sub>AS</sub>in (target word) le.  
'This is \_\_\_\_.'

Some mothers did not utter certain target words or repeated each word four times only. As a result, a total of 2,933 tokens were obtained, 1,470 for ADS and 1,463 for IDS. The utterances were recorded using a portable Marantz digital recorder (PMD 661MKII) and a head-mounted microphone (Shure SM15A).

### 2.3. Measurements

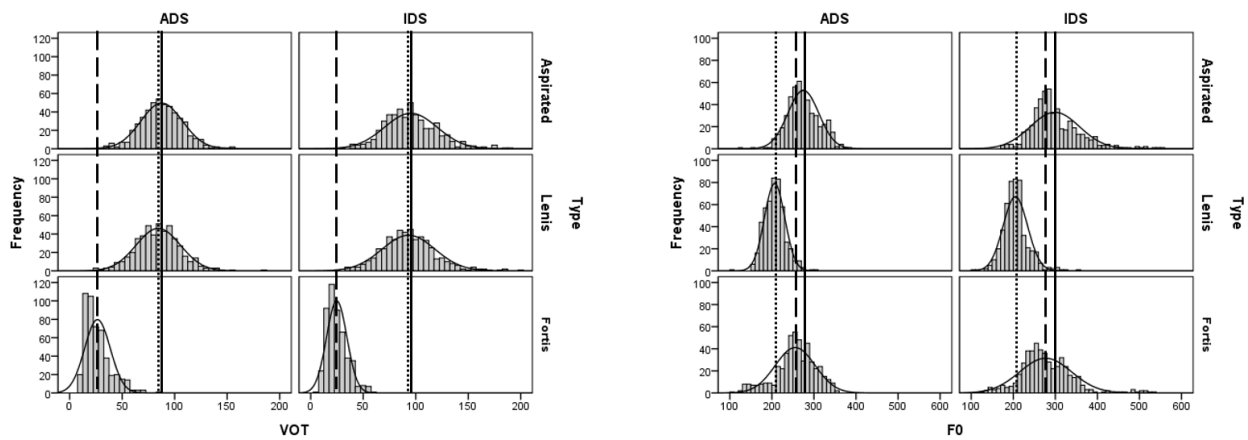
For each of the tokens obtained, two acoustic properties encoding Korean stop contrasts were measured using PRAAT [8]. VOT was measured as the time duration between the point of stop burst release and the onset of the following vowel. The F0 was measured by converting the average wavelength of the first 25 milliseconds of the vowels.

## 3. RESULTS

### 3.1. Acoustic characteristics of the maternal input

First, we report the overall characteristics of VOT and F0 produced by the mothers in the present study. Figure 1 shows the distribution of VOT (left panel) and F0 (right panel) values for each stop category (aspirated, lenis, and fortis), split by speech register. In both IDS and ADS, the VOT of fortis was shorter than the other two categories. The VOT range for the lenis stops overlapped almost completely with the ranges from the aspirated stops in both ADS and IDS speech types. Additionally, we analysed VOT differences between each pair by speech register (see Table 2). The VOT difference between aspirated and lenis was not significantly different by speech style ( $F(1,32) = 0.21$ ,  $MSE = 60.29$ ,  $p = .651$ ). Further comparisons showed that the VOT differences between the fortis and lenis stops ( $F(1,32) = 32.44$ ,  $MSE = 56.748$ ,  $p < .01$ ) and between the aspirated and fortis stops ( $F(1,32) = 31.47$ ,  $MSE = 49.23$ ,  $p < .01$ ) were significantly different by speech style,

**Figure 1.** Distribution of VOT and F0 cues in three stop categories (top panel: aspirated, middle panel: lenis, & bottom panel: fortis) produced by Korean mothers in ADS (left panels in each) and IDS (right panels in each). Vertical lines indicate mean values.



indicating that the differences were greater in IDS than ADS when they involve the fortis category.

The distribution of F0 values showed that aspirated and fortis stops were overall higher than lenis stops. A repeated measures ANOVA revealed that the F0 difference between aspirated and fortis was not significantly different by speech style ( $F(1,32) = .402, MSE = 217.743, p = .531$ ). The F0 differences between the fortis and lenis stops ( $F(1,32) = 11.46, MSE = 737.308, p < .01$ ) and between the aspirated and lenis stops ( $F(1,32) = 15.60, MSE = 657.359, p < .01$ ) were significantly different by speech style. Thus, mothers were more likely to produce more distinctive F0 cues to differentiate the aspirated and lenis pair, and fortis versus lenis pair when they speak to their infants as compared with other adults.

Consistent with previous IDS research [9], the tokens in IDS distributed more widely which suggests that Korean mothers tend to provide more variable tokens of stop categories to their infants. Interestingly, however, Korean mothers selectively enhanced the relevant cues for particular sound pair. For instance, they enhanced VOT differences by about 10ms in IDS for the aspirated-fortis pair where the VOT serves as the primary cue for distinction. By comparison, F0 cue differences were overall

enhanced for the lenis-aspirated and the fortis-lenis pairs where the F0 is useful in their discriminations.

### 3.2. Individual differences in how mothers speak the three-way laryngeal contrasts: modern way vs. traditional way

Second, we examined the variability in production of VOT and F0 cues among these mothers. According to Kang [3], the estimated VOT differences between the aspirated and lenis stops were 5.56ms for speakers born in 1984. Also, Kong and her colleagues [4] showed the estimated F0 differences between the aspirated and lenis stops were about 75 Hz (cf. Fig. 2 in [4]). Based on the average differences in VOT and F0 cues produced by each mother, we separated them into two groups: (1) those who produce the cue “the modern way” and (2) those that produce the cue “the traditional way.” The criterion for VOT for this division was 5.56ms: if the mothers on average produced the VOT difference shorter than 5.56ms they are considered as producing the cue “modern way” but as “traditional way” if the difference was larger than 5.56ms. Similar approach was applied to the use of F0 cue, so using the cutoff 75Hz, those mothers that produced the F0 difference between aspirated and lenis greater than 75Hz were considered producing the cue “a modern way” and vice versa for other mothers.

Table 3 shows the distribution of individual mothers based on their unique cue production pattern. Among 33 mothers, 20 mothers (60%) produced VOT in the modern way whereas 13 of them still produced VOT difference in the traditional way. Somewhat surprisingly for F0, only ten mothers (30%) produced the difference in line with the recent change but 23 of them (70%) still produced F0 difference less than 75Hz, following the traditional pattern. Mothers who produced both VOT and F0 reflecting the

**Table 2:** Mean differences in VOT and F0 among the three sound pairs between ADS and IDS register.

Comparison pair	VOT (ms)			F0 (Hz)		
	mean	SD	<i>F</i>	mean	SD	<i>F</i>
Aspirated & Lenis						
ADS	3.17	10.24	0.208	68.46	26.15	15.60**
IDS	2.3	12.29		93.39	47.16	
Fortis & Lenis						
ADS	57.73	13.68	32.44**	49.52	29.21	11.46**
IDS	68.29	17.46		72.15	45.3	
Aspirated & Fortis						
ADS	60.9	14.52	31.47**	18.94	20.44	0.402
IDS	70.59	16.59		21.25	24.59	

\*\*  $p < .01$

**Table 3:** Individual cue use pattern in Korean mothers' production of laryngeal contrasts.

	VOT		F0		Both VOT and F0	
	Modern Way	Traditional Way	Modern Way	Traditional Way	Modern Way	Traditional Way
<i>N</i>	20	13	10	23	5	8
%	60%	40%	30%	70%	15%	24%
Mean Age	31.7	32.9	32.9	31.9	32.6	32.8
Grew up Region						
Seoul	16	8	7	17	5	7
GyungSang	2	3	2	3	0	1
Other	2	2	1	3	0	1

Note: VOT difference < 5.56ms & F0 difference > 75 Hz between lenis and aspirated pairs considered 'modern.'

complete tonogenetic change were relatively minor, consisting of 15% of the total ( $n=33$ ). Furthermore, the age of the mothers and their exposure to different dialects during childhood did not seem to matter systematically.

These results showed that Korean mothers were not monolithic in producing their stop contrasts, showing that some mothers were still producing VOT and/or F0 cues in the traditional ways. It also showed that the shifts in VOT were not always accompanied by F0 shifts within an individual: in fact, shifts in VOT seems to be occurring ahead of F0 shifts. These results may be an indication that the process of tonogenesis is yet to be completed in terms of the input provided for Korean learning infants today.

### 3.3. Do dialects matter?

Third, we analysed the effects of dialects. As it has been reported that the tonogenesis occurred earliest in Seoul first [1], it could be the case that mothers who grew up outside of Seoul produce stop contrasts differently from those who grew up in Seoul.

To test this possibility, we examined the effect of mothers' dialects (Seoul, GyungSang, & Other, we combined the rest into other) on the magnitude of VOT and F0 differences on each pair, using a repeated measures ANOVA. But no significant effects of dialects were observed ( $F_s < 2.37, p_s > .11$ ) across all pairs, except that the F0 difference between the aspirated and fortis pair was marginally significant by dialects ( $F(2,30) = 2.941, MSE = 717.587, p = .068$ ).

Although we need to be cautious in interpreting the results as we only had a limited number of participants, the results thus far suggest that mothers who grew up in other areas than Seoul did not differ much from those who grew up in Seoul in the way they enhanced the cues that are relevant for the discrimination of stop contrasts in IDS.

## 4. DISCUSSION

The present paper examined how mothers of Korean learning infants today produce three-way stops. As Korean is going through the process of tonogenesis in their speech, it is crucial to understand the nature of input from which Korean learning infants are to learn the laryngeal contrasts in stops.

First, we observed that Korean mothers' use of VOT and F0 cues has changed further in recent years, compared with prior report [7]. The mothers of 7-9-month-olds in our data selectively enhanced VOT differences for fortis-lenis & fortis-aspirated pairs and F0 differences for lenis-aspirated pair, showing that mothers tended to enhance relevant cues for specific pair discrimination.

However, it is important to point out that the variability of acoustic cue distributions in IDS was quite large. And the mothers varied in their production of VOT and F0 cues, some showing complete change while others do not. This is consistent with previous studies [9, 11] in many other languages where IDS speech are more variable in almost every measure that has been investigated. Furthermore, we need to be cautious in interpreting our results because our participants were mostly Seoul Korean speakers and their speech was elicited one, unlike [7]. As pointed out by [11], spontaneous speech would differ and be more variable in acoustic characteristics. Our tokens were also nonsense syllables and therefore, it was possible that our data was limited to fully observe the change because frequent words are the ones driving the sound change [3]. Future studies will need to address these issues.

Overall, our findings suggest that tonogenesis is still an on-going process for infants learning Korean. And the input to Korean-learning infants is likely mixed with speakers of different generations, speech styles, and other potential factors, such as word frequency.

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## 6. REFERENCES

- [1] Beckman, M. E., Li, F., Kong, E. J., & Edwards, J. (2014). Aligning the timelines of phonological acquisition and change. *Laboratory phonology*, 5(1), 151-194.
- [2] Bang, H. Y., Sonderegger, M., Kang, Y., Clayards, M., & Yoon, T. J. (2015). The effect of word frequency on the time course of tonogenesis in Seoul Korean. In *Proceedings of the 18th International Congress of Phonetic Sciences (ICPhS2015)*.
- [3] 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.
- [4] Kong, E. J., Beckman, M. E., & Edwards, J. (2011). Why are Korean tense stops acquired so early?: The role of acoustic properties. *Journal of Phonetics*, 39(2), 196-211.
- [5] Silva, D. J. (2006). Acoustic evidence for the emergence of tonal contrast in contemporary Korean. *Phonology*, 23(2), 287-308.
- [6] Choi, Y., Nam, M., Shin, M., Mazuka, R., & Yamane, N. (2017). Emergence of Korean infants' ability to discriminate the three-way stop contrasts: Contributions of initial biases and nature of input. *14th International Congress for the study of Child Language (IASCL 2017)*. Lyon, France.
- [7] Ko, E. (2016). Evaluating the clear speech hypothesis of child-directed speech: The case of Korean stop consonants. *The Korean Society of Speech Sciences (KSSS 2016)*. Seoul, Korea.
- [8] Boersma, P., & Weenink, D. (2005). Praat: doing phonetics by computer. 2009. Online: <http://www.praat.org>.
- [9] Soderstrom, M. (2007). Beyond baby talk: Re-evaluating the nature and content of speech input to preverbal infants. *Developmental Review*, 27(4), 501-532.
- [10] Liu, H. M., Kuhl, P. K., & Tsao, F. M. (2003). An association between mothers' speech clarity and infants' speech discrimination skills. *Developmental Science*, 6(3), F1-F10.
- [11] Miyazawa, K., Shinya, T., Martin, A., Kikuchi, H., & Mazuka, R. (2017). Vowels in infant-directed speech: More breathy and more variable, but not clearer. *Cognition*, 166, 84-93.