

Tonogenesis in early Contemporary Seoul Korean: A longitudinal case study

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Abstract

A series of recent apparent time studies observed that Seoul Korean is undergoing a tonogenetic sound change whereby the VOT contrast between aspirated and lenis stops in phrase-initial position is being merged and the contrast between the stop categories is more reliably signalled by difference in F0 of the following vowel. This paper presents an instrumental phonetic study of aspirated and lenis stops in early 20th century Seoul Korean based on audio recordings of elementary school textbooks from 1935. The two speakers examined in the 1935 recordings are one 41-year-old male speaker and one 11-year-old male speaker. The data from the 1935 is also compared to the speech of the child speaker from 1935 re-recorded 70 years later in 2005 at the age of 81 to examine the change of a speaker's speech over his lifespan. The results confirm that a tonogenetic sound change has been in progress over the last century or so in Seoul Korean; the 1935 adult male speaker relied almost exclusively on VOT difference for the stop contrast unlike Present Day Seoul speakers of comparable age and gender, who make use of both VOT and F0 cues to signal the stop contrast; the 1935 child speaker rely on F0 cue for stop contrast more than the 1935 adult in line with the general direction of sound change; the 1935 child speaker at the age of 81 in 2005 showed even more F0 differentiation than he did 70 years earlier showing that the speaker underwent change in the direction of community-level sound change over his lifespan. The study is significant in that this is the first longitudinal instrumental phonetic study of tonogenetic sound change.

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1. Introduction

Tonogenesis is a commonly attested sound change whereby consonantal contrasts of voicing, aspiration and glottalization, or phonation contrast of breathiness and creakiness give rise to and eventually become replaced by tonal contrasts (Haudricourt, 1971; Maran, 1973; Matisoff, 1973; Hombert, 1978; Hombert et al., 1979; Thurgood, 2002; Kingston, 2011). In many cases, tones start out as redundant phonetic attributes of consonantal contrast (e.g., ba vs. pa), then develop into a robust distinction coexisting with the original consonantal contrast (bà vs. pá), and finally become the primary contrastive feature (pà vs. pá), as the original consonantal features are lost. Many studies reconstruct tonogenetic sound change by comparing linguistic data from different time periods of a language or synchronic data from related dialects and languages, where some of the dialects and languages retain the earlier state of consonantal contrast while others have replaced the consonantal contrasts with tonal contrasts (Karlgrén, 1966; Haudricourt, 1971; Matisoff, 1973;

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Kingston, 2005). There are also a number of instrumental phonetic studies of languages in a state of transition from consonantal to tonal contrast (Mazaudon and Michaud, 2008; Chen, 2011; DiCano, 2012) and also a phonetic study that compares different endpoints of sound change by examining related dialects of a language, one that retains the original consonantal contrast and another that replaced the consonantal contrast with a tonal contrast (Svantesson and House, 2006). Also, there are studies that examine contact-induced synchronic variation in the realization of tonal contrast along a tonogenetic trajectory (Pearce, 2009; Brunelle, 2009). Relatively rare are instrumental studies that examine the diachronic sound change within a single speech community. Hyslop (2009) and Abramson et al. (2004) are notable exceptions in that they examined variation within a speech community with an eye to tracking diachronic sound change but these studies are limited in their scope. Also, as far as we know, there is no instrumental study that examines a tonogenetic sound change in a single dialect of a language across real time or a longitudinal study of same speakers over time.¹

Contemporary Seoul Korean (1890–present) presents an ideal opportunity to examine this sound change in progress. Korean has a three-way laryngeal contrast of voiceless stops, among aspirated stops /p^h, t^h, k^h/, lenis stops /p, t, k/, and fortis stops /p', t', k'/. Previous studies show that the contrast is signalled by a combination of acoustic cues including voice onset time (VOT) of the stop and fundamental frequency (F0) and amplitude difference between the first and the second harmonics (H1–H2) of the following vowel; aspirated stops have the longest VOT values, fortis stops have the shortest values, and lenis stops have intermediate values; F0 on the following vowel is higher for aspirated and fortis stops than for lenis stops; vowels following aspirated and lenis stops have breathier voice quality than vowels following fortis stops as indicated by higher H1–H2 values (Cho et al., 2002; Hardcastle, 1973; Han and Weitzman, 1970; Kang and Guion, 2008; Kim, 1965, 1994; Lisker and Abramson, 1964).

There are a number of recent apparent-time studies on the emergence of tonal contrast in Seoul Korean (Silva, 2002, 2006; Wright, 2007; Kang and Guion, 2008; Kang, submitted for publication). These studies show that Seoul Korean is in fact in the process of losing the VOT (Voice Onset Time) contrast between aspirated and lenis stops (/p^h t^h k^h/ vs. /p t k/) in phrase-initial position and the formerly redundant pitch difference—a high pitch on vowels following aspirated stops and a low pitch on vowels following lenis stops—is replacing the VOT difference as primary cue of the contrast. A similar change is reported for dialects of Korean spoken in Chinese (Jin, 2008) and in Toronto (Kang and Nagy, 2012).

An Accentual Phrase (AP) is a crucial unit in the realization of tones in Present Day Korean. An AP is a unit of prosodic structure that is above Prosodic Word and below Intonational Phrase in prosodic hierarchy of Seoul Korean (Jun, 1993). Accentual Phrases (AP) are marked by boundary tones and the initial boundary tones vary between LH and HH depending on the laryngeal feature of the AP-initial consonant; AP's that begin with a lenis stop or affricate or a sonorant are marked by LH boundary tones with L falling on the initial syllable and H on the second, while phrases that begin with a fortis or aspirated stop or affricate, /h/, or coronal fricatives, are marked by HH boundary tones with H falling on each of the first two syllables (Jun, 1993). The consonant-induced F0 difference extends far beyond the initial portion of the immediately following vowel indicating that the F0 perturbation is not an automatic consequence of physiological restrictions in laryngeal articulation (Jun, 1996; Kim, 2000; Silva, 2006). Recent perception studies also find that F0 is a crucial perceptual cue for stop distinction, for lenis-aspirated stops in particular (Kim et al., 2002; Kim, 2004; Lee and Jongman, 2011; Kong et al., 2011). So, this recent change in Seoul Korean is consistent with a process of tonogenesis, whereby consonant-induced F0 perturbation is exaggerated and reinterpreted by learners as a primary contrast, eventually replacing the original voicing or phonation contrast of consonants (Hombert et al., 1979; Kingston, 2011).

The merger of VOT is almost complete in the speech of younger female speakers, a population known to lead many sound changes, and the least advanced in the speech of older male speakers. The F0 contrast is further enhanced in younger and female speakers' speech. Fig. 1, reproduced from Kang (submitted for publication), shows the variation in VOT values of sentence-initial stops and F0 at the midpoint of following vowel by speakers' age and gender based on the NIKL (The National Institute of the Korean Language) acoustic corpus of Standard Seoul Korean (2005).

It is notable that even the oldest male speakers shown in Fig. 1, i.e., those born in the 1930s, exhibit substantial consonant-induced pitch difference of around 2 semitones at the midpoint of following vowel, indicating that the tonogenetic process have already advanced fairly far in Present Day Korean. At the same time, these speakers show a robust contrast of VOT between aspirated and lenis stops, showing a difference of over 40 ms in mean VOT values, indicating that the sound change has not progressed far enough for F0 to overtake VOT as the primary exponent of the contrast. Given what we know about the general trajectory of tonogenetic sound change (cf. Maran, 1973), we expect that the preceding stage of Seoul Korean had a similarly more robust VOT contrast between aspirated and lenis categories but less distinctive F0 difference between the two stop categories.

In apparent-time studies (Labov, 1963; Bailey et al., 1991), it is assumed that the individual speakers' speech remains more or less stable across life span reflecting the state of language at the time they learned the language and that differences among speakers of different generations at a single point in time mirror diachronic change in real time. While it

¹ Zsiga (2008) examined the change in the realization of contour tones in Thai but not the emergence of tones themselves.

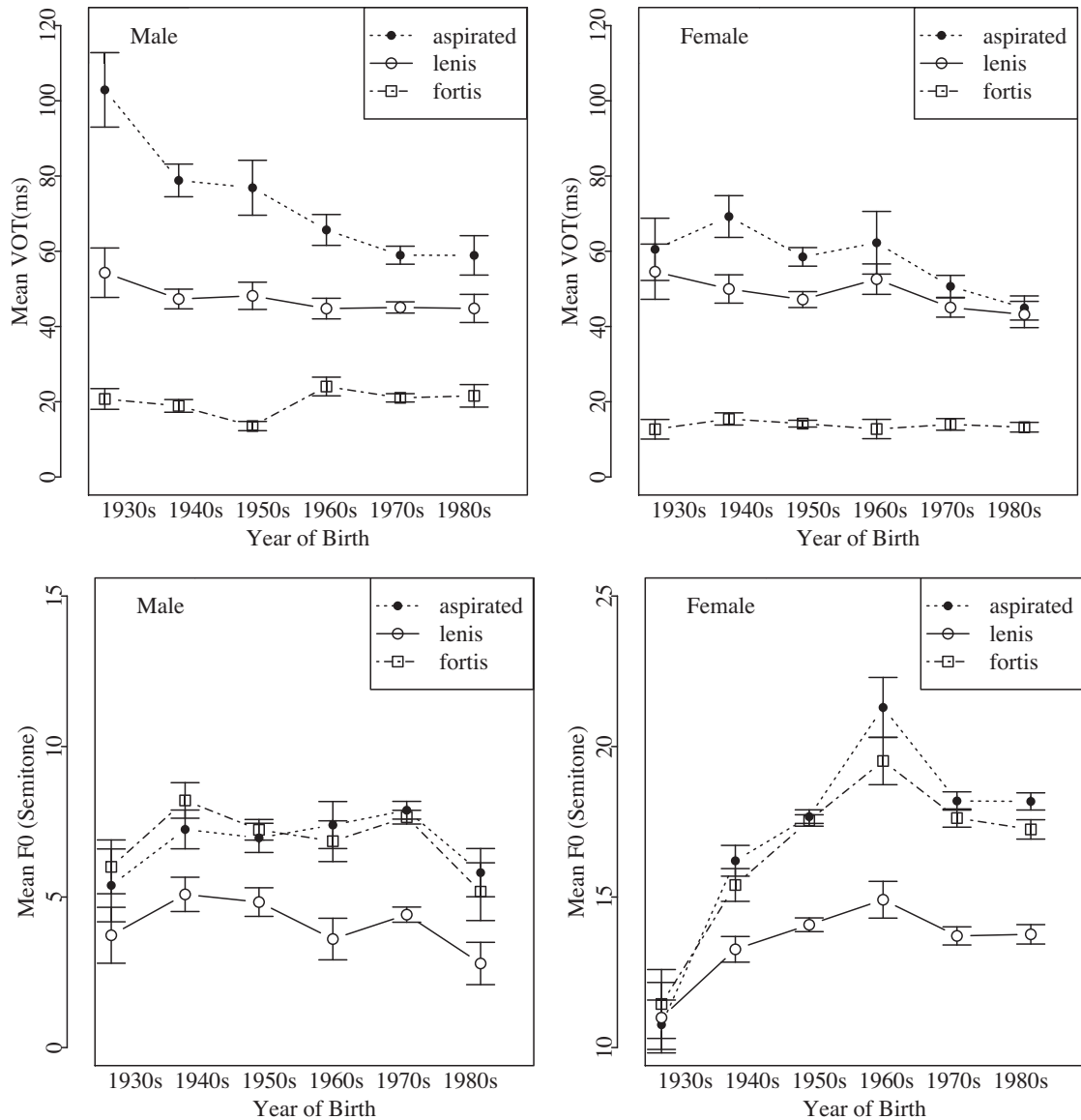


Fig. 1. (a) Mean VOT (ms) and (b) mean F0 (semitone, reference = 100 Hz) at following vowel midpoint of three stop categories by speakers' year of birth, aggregated by 10 year bands, for speakers of Seoul Korean recorded in 2003. The error bars represent 95% confidence interval. From Kang (submitted for publication).

has been shown that the apparent time study of linguistic change is a reliable reflection of linguistic change in real time for the most part (Bailey et al., 1991), there are factors that affect the age-dependent variation other than community-level language change, such as age-grading and change across life span (Boberg, 2004; Sankoff, 2005; Sankoff and Blondeau, 2007). Age-grading refers to the type of variation, where as speakers grow older, they take on a speech style that is appropriate for their age and gender. In this case, we can get age-dependent variation synchronically while the language at the community level does not undergo any change. Change across life span refers to a situation where adult speakers undergo language change over the course of their lifetime in a direction consistent with the general direction of community-level sound change. In the latter case, an apparent time study of language change underrepresents the rate of change showing a less differentiation between older and younger speakers than corresponding difference over real time. Therefore, to gain a fuller picture of sound change, a comparison of data from different time periods (trend study) and a longitudinal study of individual speakers across their life span (panel study) are helpful.

In this paper, we examine the stop consonant production in an earlier stage of Seoul Korean than has been examined by previous studies. We present an acoustic study of the speech of one 41-year-old male and one 11-year-old male

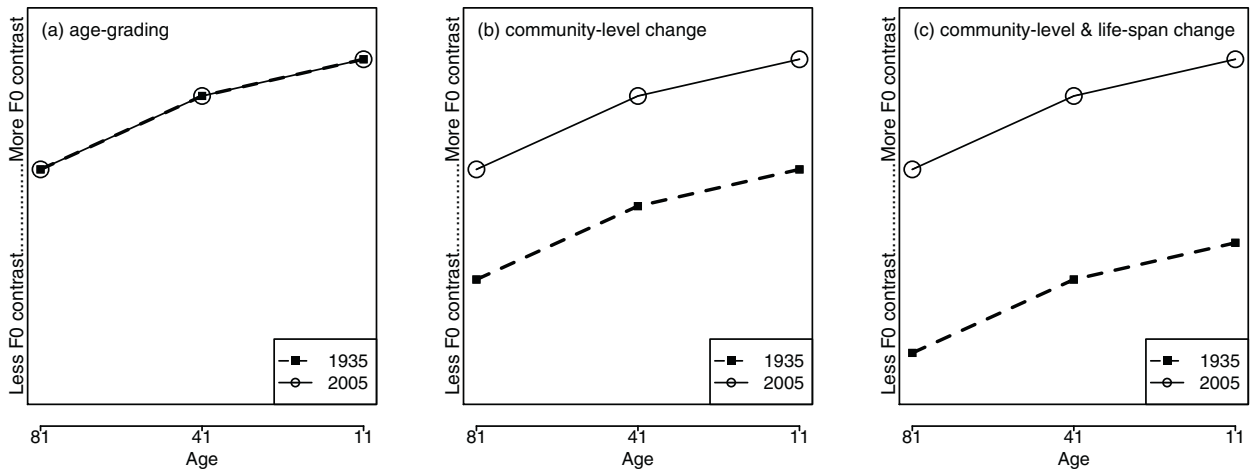


Fig. 2. Schematic representations of expected age-conditioned variation in 1935 and 2005 under (a) age-grading, (b) community-level change, and (c) community-level change along with life-span change.

speaker of Seoul Korean from 1935 and the speech of the latter speaker re-recorded in 2005 at the age of 81. We examine whether and how the three sets of speech data differ from one another and from the speech of Present Day Seoul Korean speakers of comparable age and gender. As mentioned above, in Present Day Korean, older male speakers retain a relatively large VOT difference between aspirated and lenis stops and produce substantial F0 contrast on the vowels following the stops, although the degree of F0 contrast is less than in younger speakers. We expect that the speech of the 81-year old male (year of birth: 1924), recorded in 2005 will show a similar pattern and the contrast of aspirated and lenis stops is signalled by reliable difference both in VOT and F0.

Several predictions can be made about the speech of the speakers in 1935. If the age-conditioned variation in 2005 is due to age-grading and a similar age-grading pattern was active in 1935, we expect that speakers of 1935 will mirror the speech patterns of comparable age groups in 2005. This prediction is schematically represented in Fig. 2, adapted from Boberg (2004). In the graphs, the x-axis represents the age of the speaker, the y-axis represents the degree of progress along the relevant change, i.e., increased use of f0 contrast, the dotted line represents the 1935 pattern and the solid line represents the 2005 pattern. If age-grading is responsible for the age-conditioned variation, the two lines will coincide with each other as shown in Fig. 2(a). So, we expect more conservative pattern in the speech of 81-year-old speaker in 2005 than in the speech of the two 1935 speakers.²

On the other hand, if the synchronic variation in Present Day Korean is due to sound change in progress, we expect that the 41-year-old speaker in 1935, who is a whole generation ahead of the 81-year-old speaker of 2005 in real time, to produce a more conservative speech pattern than the 81-year-old speaker as schematically shown in Fig. 2(b) and (c). Less clear is what to expect from the 11-year-old speaker in 1935. It has been suggested that during the age of language acquisition, assumed to be up to and around the age of 4, children acquire the speech of their caregiver, female in most cases, but beyond this initial acquisition period, they start to deviate from their caregiver's speech and take on the speech style of their peer groups in their adolescent years, injecting further changes to the language (Labov, 2001; Tagliamonte and D'Arcy, 2009). It has been noted that in female-led sound changes, this change during adolescence is not limited to but most notable with girls, creating the commonly attested gender asymmetry whereby female speakers push the change further than male speakers. Even after the teenage years, individual speakers may continue to change their speech Sankoff and Blondeau (2007), for example, showed that some, not all, speakers of Montreal French changed their pattern of [r] production along the overall direction of sound change during their adult years. Since our speaker is male, there is no clear prediction as to whether the speakers' speech may have changed over the 70 years between the two recordings. But, in either case, if there is indeed a sound change in progress at the community level, we expect that the 1935 child speech is at least as conservative (without any change across life span) or even more conservative than his own speech 70 years later (with change across life span). These two predictions are schematically represented in Fig. 2(b) and (c).

² Studies on the stop production by children, ranging in age from 2 to 10 years, in Present Day Korean show that children produce a substantial overlap of VOT values between aspirated and lenis stops and more reliable difference in F0 (Kim and Stoel-Gammon, 2009; Kong et al., 2011; Lee and Iverson, 2012) in line with younger adult speakers' speech pattern.

Table 1
Speakers examined in the study.

Speaker T		41-year-old male speaker from 1935
Speaker S	S1	11-year old male speaker from 1935, first round of production
	S2	11-year old male speaker from 1935, second round of production
	SA	81-year old male speaker from 2005, the same individual as the 11-year old male speaker from 1935

2. Materials and methods

The data from 1935 is drawn from the recording of elementary school textbooks, *Pothonghakkyo Cosunetokpon* 'Korean reader for normal school', which were first published in 1911 and underwent several revisions over the years. The recording consists of 27 tracks and the speakers were a group of 5th graders attending *Kyengseng Sapem Pusok Pothong Hakkyo*, an elite elementary school in Seoul and a 41 year-old male, Mr. Shim Uy-Lin, who was a linguist and also a teacher at the school. They were all speakers of Seoul Korean born and raised in Seoul. The recording was published as an SP by a Japanese recording company, OKEH in 1935, and reproduced in a CD format by Koyang Cultural Foundation in 2004 (Koyang Cultural Foundation, 2004). A detailed phonological study of the recording is found in Han (2005). The data for the current paper is from track #2, which is a reading of Korean syllabary. In this track, Mr. Shim, the teacher, recites the Korean syllabary and Mr. Chung Kye-Whan, then an 11-year old boy, repeats after the teacher after each two-syllable sequence. Once they went through the entire syllabary, the younger speaker recites the entire syllabary by himself. In 2005, the second author re-recorded the reading of the textbook by Mr. Chung Kye-Whan, by then 81 years old. The recording was initially made in an analogue tape and later digitized for acoustic analysis. For the rest of the paper, we will refer to Dr. Shim Uy-Lin as T (for Teacher), Mr. Chung Kye-Whan as S (for Student), with S1 referring to the first round of production and S2, the second, and the production by Mr. Chung Kye-Whan of 2005 as SA (for Student-Adult). The speaker labels are summarized in Table 1.

Fortunately for our purpose, Korean syllabary provides a controlled dataset for the study of Korean consonants, and their effect on the pitch of the following vowels. The syllabary consists of 140 syllables in total, which are combinations of 14 onsets (/p p^h t t^h k k^h c c^h s h m n l/ and null) and 10 vowels or glide-vowel sequences (/a ja ə jə o jo u ju i/). For example, the first line of syllabary is /ka-kja kə-kjə ko-kjo ku-kju ki-ki/, with each two syllable sequence read as a unit, roughly corresponding to an Accentual Phrase (AP).³ As the AP-medial lenis stops are allophonically voiced and only AP-initial consonants induce substantial tonal contrast on the following vowel in Present Day Korean, we will focus on the realization of AP-initial consonants. Due to extraneous noise, a few tokens are excluded from analysis. As a result, our data consists of a total of 70 two-syllable phrases for speaker T (Teacher from 1935), 69 for SA (Student as adult in 2005), and 138 for S (Student in 1935) (68 for S1 and 70 for S2).

Note that not all consonants and vowels of Korean are represented in the syllabary. Table 2 provides the full inventory of Korean consonants and monophthongal vowels. Missing from the syllabary are /ŋ/, which does not occur in onset position. Also missing from the syllabary are all fortis consonants /p' t' k' c' s'/, non-high front vowels /e ε/, and various glide + vowel sequences. These sounds are represented by combinations of basic symbols. For example, fortis consonants are represented by doubling of the symbol for corresponding lenis consonant. The absence of fortis consonants is particularly unfortunate but as the main focus of our study is the change in the relationship between the lenis and the aspirated obstruents, the data is adequate in that regard.

Table 2
The inventory of Korean consonants and monophthongal vowels.

p p ^h	t t ^h	k k ^h	
	c c ^h		
	s s'		h
m	n	ŋ	
	l		

i	ɨ	u
e	ə	o
ε	a	

³ But see footnote 6 (current footnote 5).

The acoustic analysis was conducted using *Praat* (Boersma and Weenink, 2011). For all phrase-initial CV sequences in the data, the onset of stop release, the onset of voicing on the vowel and the offset of the vowel were manually identified. The quality of the recording was less than ideal and while the vowel onset and offset can be identified reliably, the onset of stop release was often not clearly visible on the waveform or spectrogram. We tried the noise removal function of *Audacity* on the data but it did not make a noticeable improvement. To ensure the reliability of analysis, the manual segmentation was conducted twice, once by a research assistant, who was naïve as to the purpose of the study and did not know Korean, and once by the first author. Pearson's product-moment correlation between the VOT (Voice Onset Time) measurements based on the two segmentations was highly significant ($t = 211,395$, $df = 114$, $p < 0.0001$, $r = 0.8926$). Here, we will report the result based on the segmentation by the first author with the assurance that the results based on the alternative segmentation support the same overall conclusion.

The acoustic measurements included the Voice Onset Time (VOT) of the AP-initial stops, and the duration and fundamental frequency (F0) of the vowel following the initial stop. VOT was defined as the duration from the onset of the stop release to the zero crossing at the upward swing of the first periodic cycle of the following vowel. The F0 was measured at several time points during the vowel, 15 ms and 30 ms after the onset of voicing, as well as at 25%, 50%, and 75% point of vowel duration, to examine how far into the vowel the consonant-induced pitch difference extends. Here we report the measurements at 15 ms after the onset of voicing and at the temporal midpoint of the vowel. *Praat's* pitch tracking function was used with pitch range set at 75–500 Hz. All measurements were extracted using scripting function of *Praat* followed by a manual check of pitch tracks for any irregularity or error. As we are comparing the pitch pattern of speakers at three different ages, F0 measurements in Hz are converted to semitones (St), a logarithmic scale of pitch, which allows for comparison of pitch range across gender and age (Whalen and Levitt, 1995; Oh, 2011). St was calculated with 100 Hz as a reference pitch using the formula, $\log_2(\text{Hz}/100) \times 12$. Of primary interest to us is how our speakers use the combination of the acoustic cues, VOT of the initial stops and the F0 of the following vowel to signal the contrast between the aspirated and lenis stops. Statistical tests were conducted in *R* (R Development Core Team, 2011).

3. Results

We first examine the VOT and F0 values of the stops separately and then examine how the weighting of the two cues change from speaker to speaker. The data from the two sets of productions by speaker S as a child are reported separately as S1 and S2 because the two repetitions are produced under different conditions, S1 as repetitions of teacher's speech, and S2 as independent production but as a second reading of the material. Table 3 summarizes the mean VOT values of each stop category for each dataset. In all four datasets, the VOT values are substantially longer for aspirated stops than for lenis stops. A paired-samples *t*-test was conducted for each dataset to compare the VOT values of aspirated and lenis stops and there was a significant difference in all four datasets (T: $t(12) = 91,287$, $p < 0.0001$; S1: $t(14) = 84,903$, $p < 0.0001$; S2: $t(13) = 7501$, $p < 0.0001$; SA: $t(13) = 75,701$, $p < 0.0001$). In line with cross-linguistic tendencies, the VOT values are longer for stops with more posterior places of articulation (Dorsal > Coronal > Labial).

Fig. 3 shows the mean VOT difference between aspirated and lenis stops in corresponding contexts for each dataset. The mean difference is 474 ms for T, 461 ms for S1, 372 ms for S2, and 572 ms for SA. It is notable that the second production of Speaker S as a child, S2, shows the least difference between the two categories. This is likely due to the fact that this was his second repetition and his speech was less careful than the first repetition, as is common with repeated speech material (Lieberman, 1963; Fowler and Housum, 1987; Fowler, 1988). To examine whether the VOT difference by

Table 3
The mean and standard deviation (in parentheses) of VOT in ms.

Dataset	Labial	Coronal	Dorsal	Total
T				
Lenis	20.4 (5.8)	40.4 (9.4)	51.8 (25.1)	37.1 (21.1)
Aspirated	73.3 (13.2)	82.6 (5.1)	97.8 (15.4)	84.3 (15.0)
S1				
Lenis	23.2 (10.3)	37.3 (6.7)	43.2 (11.7)	34.6 (12.6)
Aspirated	78.4 (10.7)	78.9 (10.4)	84.6 (18.0)	80.7 (12.8)
S2				
Lenis	23.5 (11.5)	32.6 (72.0)	33.9 (11.4)	30.5 (10.4)
Aspirated	67.7 (14.6)	56.3 (8.8)	78.8 (16.5)	67.6 (15.8)
SA				
Lenis	34.3 (14.7)	44.8 (14.5)	51.1 (28.6)	44.0 (20.4)
Aspirated	79.3 (14.9)	84.7 (13.7)	137.0 (18.2)	100.3 (30.6)

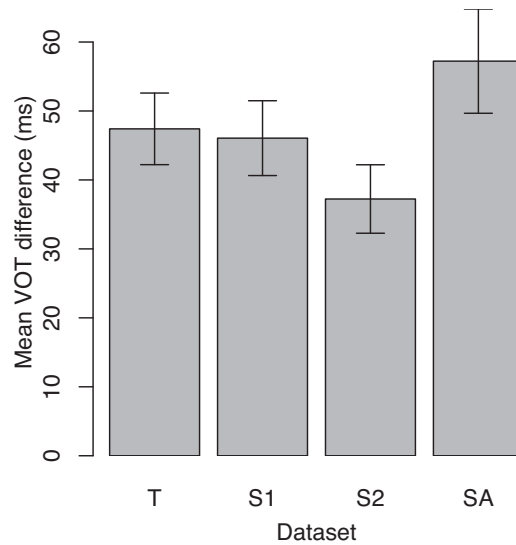


Fig. 3. The mean VOT difference between lenis and aspirated stops by each dataset.

Table 4

The mean and standard deviation (in parentheses) of F0 in Hertz and Semitone scales.

Dataset	Hertz		Semitone	
	Onset	Midpoint	Onset	Midpoint
T				
Lenis	128.0 (5.4)	123.4 (4.1)	4.3 (0.7)	3.6 (0.6)
Aspirated	134.8 (5.7)	126.5 (4.9)	5.2 (0.7)	4.1 (0.7)
S1				
Lenis	262.0 (8.5)	262.2 (8.1)	16.7 (0.6)	16.7 (0.5)
Aspirated	291.1 (9.8)	278.4 (9.3)	18.5 (0.6)	17.7 (0.6)
S2				
Lenis	292.1 (5.7)	291.2 (3.9)	18.6 (0.3)	18.5 (0.2)
Aspirated	310.8 (9.1)	296.2 (6.8)	19.6 (0.5)	19.9 (0.4)
SA				
Lenis	165.9 (13.4)	175.5 (8.2)	8.7 (1.4)	9.7 (0.8)
Aspirated	206.9 (14.7)	195.4 (7.0)	12.5 (1.2)	11.6 (0.6)

stop category is significantly different from dataset to dataset, a one-way ANOVA was conducted with the VOT difference between aspirated and lenis stop in corresponding contexts as a dependent variable and dataset as an independent variable and there was no significant effect of dataset on VOT difference [$F(3,52) = 19.305, p = 0.1361$]. In other words, overall, there was no clear trend of VOT contrast reduction from older (T) to younger speaker (S1, S2) in 1935 or from the speech of a single speaker from 1935 (S1, S2) to 2005 (SA).⁴

Now turning to F0 values, Table 4 summarizes the mean F0 values both in Hz and in Semitone units at vowel onset (measured at 15 ms after onset of voicing) and at temporal midpoint of vowel for each stop category for each speaker. In

⁴ To examine the potential effect of speech rate on VOT realization, the average vowel duration for each dataset was calculated (T: 239.6 ms; S1: 264.1 ms; S2: 316.1 ms; SA: 317.2 ms). Speaker T had a fast speech rate as indicated by a short average vowel duration. When we normalize the VOT values by dividing them by the mean vowel duration for each dataset, the overall pattern still remains the same, except that the difference between S2—where contrast reduction is expected due to repetition effect—and T and SA reach significance.

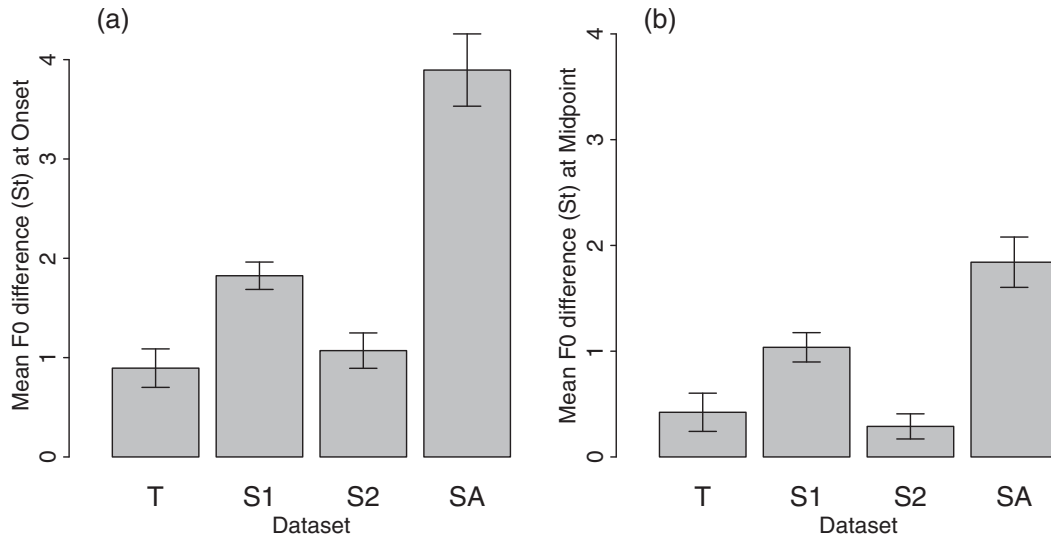


Fig. 4. The mean F0 (semitone) difference between lenis and aspirated stops by each dataset: (a) at 15 ms after the vowel onset and (b) at vowel midpoint.

all four datasets, the F0 values are substantially higher for aspirated stops than for lenis stops, both at the onset and at the midpoint of vowel. The statistical analyses reported here are conducted on the F0 values in Semitone units but the results are comparable in analyses based on F0 values in Hz units. A paired-samples *t*-test was conducted for each dataset to compare the F0 values of aspirated and lenis stops and there was a significant difference in all datasets both for the measurements at vowel onset (T: $t(14) = 46,158$, $p = 0.0004$; S1: $t(14) = 132$, $p < 0.0001$; S2: $t(14) = 6012$, $p < 0.0001$; SA: $t(10) = 10.7$, $p < 0.0001$) and at vowel midpoint (T: $t(14) = 23,366$, $p = 0.0348$; S1: $t(14) = 74,771$, $p < 0.0001$; S2: $t(14) = 24,321$, $p = 0.0290$; SA: $t(13) = 77,392$, $p < 0.0001$).

While the F0 difference is significant in all contexts for all speakers, the F0 difference was noticeably larger for SA, 410 Hz or 38 St at onset and 199 Hz or 19 St at midpoint, than for others. Also, the F0 difference was larger at vowel onset than at vowel midpoint. Fig. 4 summarizes the mean difference of F0 values between aspirated and lenis stops in corresponding contexts, at the onset and the midpoint of the following vowel.

To examine whether the F0 difference by stop category is significantly different from speaker to speaker and from the onset to the midpoint, a two-way ANOVA was conducted with the F0 differences between aspirated and lenis stops in corresponding contexts as a dependent variable and speaker (T, S1, S2, and SA) and the position in vowel (onset and midpoint) as independent variables. There was a significant effect of speaker on F0 difference [$F(3,110) = 41,996$, $p < 0.0001$] and a significant effect of position on F0 difference [$F(1,110) = 44,880$, $p < 0.0001$] with the difference being larger at vowel onset than at vowel midpoint. A Tukey's HSD post hoc test shows that the F0 difference was largest for SA, smallest for T and S2, and intermediate for S1 (SA > S1 > S2, T).

The different realization of F0 by speaker is also clearly visible in Fig. 5. The graphs show the pitch tracks of all tokens of vowels that follow AP-initial stops in normalized time with the dashed lines representing tokens of aspirated stops and the solid lines representing tokens of lenis stops. Throughout the vowels, the pitch tracks of the two stop categories are very well separated for the 2005 adult speaker (SA) while for the 1935 adult (T) and the second repetition of 1935 child (S2), the two largely overlap. For the first production of 1935 child speaker (S1), the pattern is intermediate, showing more overlap than the same speaker's production in 2005 (SA), but showing more differentiation than Speaker T's production. As was the case with VOT contrast, the child speaker is making less clear distinction of stop categories in the second repetition (S2) than in the first (S1).

The significant speaker effect on F0 difference is in contrast to the lack of significant speaker effect on VOT difference. In other words, the VOT difference between aspirated and lenis stops remained generally stable while the F0 difference increased over time, both real and apparent, with the adult male of 1935 showing the most conservative pattern, the 11-year-old boy of 1935 showing an ambiguous pattern and the older male of 2005 showing an increased contrast in F0. This indicates that in this early stage of tonogenesis, the original consonantal contrast of VOT was still retained and remained stable while the F0 contrast emerged and further amplified. The 11-year-old boy's speech underwent change to expand the F0 contrast over the 70 years.

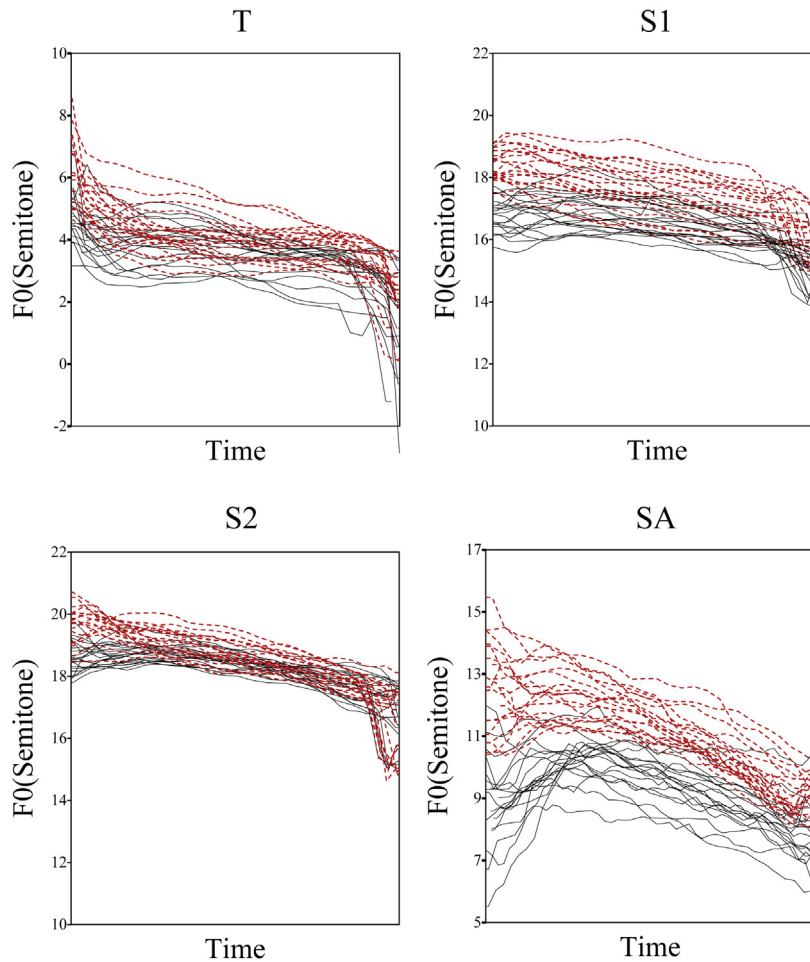


Fig. 5. The F0 (semitone) contours of aspirated (dashed lines) and lenis (solid lines) contexts in normalized time encompassing the entire vowel duration.

So far, we examined the two acoustic characteristics, VOT and F0, separately but as we are interested in change in the relative contribution of these characteristics in signalling the contrast, it will be instructive to examine both VOT and F0 cues together and see how each speaker combines the two acoustic cues to signal the contrast and which of the two cues are relied on more for signalling the contrast. For this purpose, a linear discriminant analysis (LDA) was conducted with the laryngeal category as the response variable and the VOT and F0 at vowel midpoint as the independent variables to determine to what extent each of the two acoustic cues contributes to the distinction of the stop categories. The same analysis with F0 at vowel onset, instead of F0 at vowel midpoint, produces comparable results and is not reported separately. The VOT and F0 values were normalized using z-score transformation so that the effect size of the two can be directly compared from the coefficients of linear discriminants. The coefficients values are summarized in Table 5. For the 41-year-old speaker from 1935 (T), the coefficient for VOT is larger than that for F0

Table 5
Discriminant coefficients for VOT and F0 by dataset.

Dataset	VOT	F0	Ratio: VOT/F0
T	1.5106	0.1413	10.7
S1	1.6435	0.4614	3.6
S2	1.8614	0.7936	2.3
SA	0.9255	1.3060	0.7

by the ratio of over 10 to 1, indicating that the speaker mostly relies on VOT for the stop distinction. For the 81-year-old speaker from 2005 (SA), on the other hand, the coefficient for F0 is slightly larger than that for VOT indicating that he relies on both VOT and F0 with slightly more weight on F0. The same speaker back in 1935 when he was 11 years old (S1, S2), shows the intermediate pattern with VOT outweighing F0 but the difference is not as drastic as is the case in Speaker T's speech.

It is also notable that the child speaker's two rounds of production patterns yield a comparable discriminant coefficient values while his VOT and F0 values alone give the appearance of a large difference. This suggests that while the raw values of VOT and F0 can vary significantly due to repetition effect, the relationship between the cues as revealed by linear discriminant analysis may remain relatively stable across speech types. Also, it is notable that the child speaker's coefficient ratio is more similar to that of Speaker T in the first repetition (S1), when the speaker was repeating after speaker T than in the second repetition (S2) indicating that when Speaker S was repeating after Speaker T, he made more use of VOT and less use of F0 than when he was not repeating after Speaker T. This imitation effect was not noticeable when the VOT and F0 were examined separately.

The distributional patterns of stops are visualized in Fig. 6, which shows how the two stop categories are distinguished in a two-dimensional acoustic space of VOT (in ms) by F0 (in semitones) for each dataset. For the 41-

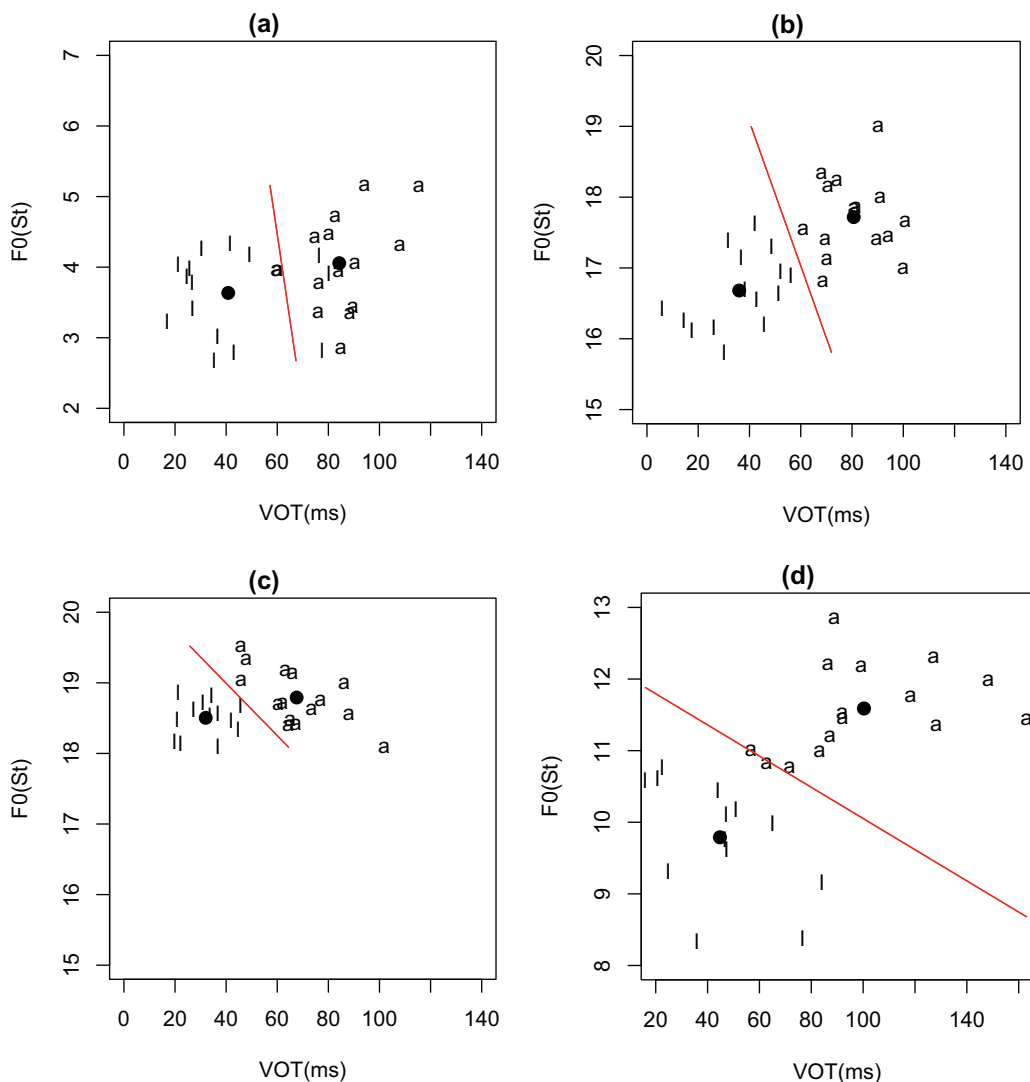


Fig. 6. The classification of lenis ("l") and aspirated ("a") stops in two-dimensional acoustic space of VOT (ms) by F0 (st) for each of the four datasets, (a) T, (b) S1, (c) S2, and (d) SA. The dots indicate the category mean and the lines indicate the category boundary based on linear discriminant analyses.

year-old speaker from 1935 (T), the boundary between the two categories is almost vertical, i.e., the distinction between the two categories is made mainly according to their VOT values, while for the 81-year-old speaker in 2005 (SA), the boundary is diagonal, showing that both VOT and F0 play a role in defining the contrast. The child speaker of 1935 (S1, S2) shows an intermediate pattern, with the boundary being more vertical than that for SA but not as vertical as for Speaker T.

4. Discussion

We found that the data from 1935 show a more conservative pattern of stop contrast than the data from 2005 as well as the data from younger speakers of Present Day Korean. Therefore, we can confirm that the age-conditioned variation in synchronic Seoul Korean cannot be attributed to age-grading (cf. Fig. 2(a)) but a reflection of genuine sound change in progress whereby the VOT contrast of aspirated and lenis stops is replaced by tonal contrast on the following vowel. We also found that Mr. Chung's speech underwent substantial change during the 70 years between the two recordings along the direction of general community-level sound change, consistent with the view that an individual speaker's speech does not necessarily remain stable as they exit the critical period of language acquisition but may undergo further changes through their lifespan (Fig. 2(c)). This result is also in agreement with the impressionistic observation by the authors that the speech of 1935 recording sounds quite different from Present Day Seoul Korean as well as the speech of Mr. Chung's in 2005, especially in the intonational patterns.

The results suggest that the synchronic age-dependent variation of stop production likely underestimates the rate of sound change in real time and the emergence of tonal contrast in Seoul Korean is in fact fairly recent, contrary to the suggestion by Silva (2006). In other words, even though many speakers of Present Day Seoul Korean in their 70s and 80s show substantial F0 contrast between stop categories, it is likely that this is not because this stage of sound change was already complete during the period of acquisition for these speakers (1920s and 1930s) but the change was just emerging during the 1920s and 1930s. Partial support for this view comes from the fact that even in the synchronic data presented in Fig. 1, some of the older female speakers in fact show minimal F0 difference between lenis and aspirated stops, similar to the pattern shown by the speakers in 1935. Sankoff and Blondeau (2007) showed that in their study of Montreal /r/, while some speakers underwent further change during their adult years in the direction of general sound change, there are speakers who retained their older pattern. It seems that we are also seeing this mixed pattern from our oldest speakers in Present Day Korean, some undergoing further changes while others not.⁵

It is worth noting that the tonal contrast examined in this study is restricted to Accentual Phrase-initial position. Kim (2000) finds that in phrase-medial position, the effect of laryngeal feature of consonants on the f0 of the following vowel is minor and localized to vowel onset.⁶ In other words, in phrase-medial position, the contrast between lenis and the other two stop categories is robustly signalled by other acoustic differences such as allophonic voicing of lenis stops (Hardcastle, 1973; Han and Weitzman, 1970; Lisker and Abramson, 1964) and closure duration difference (Han, 1996). It remains to be seen whether further development of this sound change will extend the tonal contrast emerging in the phrase-initial position to phrase-medial position, leading to a reanalysis of laryngeal contrast in stops as a tonal contrast on vowels at the phonemic level.

While the present study is limited to a speech of two male speakers, the study is valuable in that it is the only instrumental acoustic study of Korean stops from data before 1945 and also the only longitudinal instrumental phonetic study of tonogenetic sound change and confirmed that Seoul Korean has been indeed undergoing tonogenetic sound change. Future studies will examine other recordings from the 1930s to overcome the limitation of the current study.

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⁵ In this respect, it is interesting to note that in an interview with Mr. Kye-Whan Chung produced by Koyang Cultural Foundation included in the CD of textbook recordings, we can see that he is a highly-educated and upwardly mobile person; he is an avid photographer and a life-long lover of classical music, well-known in classical music scene as a fixture at the *Seoul Arts Centre*, a premier cultural performance venue in Seoul.

⁶ An anonymous reviewer wonders if the word-medial stops in the current data can be examined for the effect of laryngeal feature on the f0. The examination of data suggests that the stops in the second syllable are realized as if it is phrase-initial, i.e., without any allophonic voicing on lenis stops, and their VOT and f0 values pattern almost exactly like their initial counterpart. This is not surprising given the semi-reduplicative nature of these phrases.

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