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Inter-speaker and intra-speaker variability on sound change in contemporary Korean

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Abstract

Besides their effect on the f0 contour of the following vowel, Korean stops are undergoing a sound change in which a partial or complete consonantal merger on voice onset time (VOT) is taking place between aspirated and lax stops. Many previous studies on sound change have mainly focused on group-normative effects, that is, effects that are representative of the population as a whole. Few systematic quantitative studies of change in adult individuals have been carried out. The current study examines whether the sound change holds for individual speakers. It focuses on inter-speaker and intra-speaker variability on sound change in contemporary Korean. Speech data were collected for thirteen Seoul Korean speakers studying abroad in America. In order to minimize the possible effects of speech production, socio-phonetic factors such as age, gender, dialect, speech rate, and L2 exposure period were controlled when recruiting participants. The results showed that, for nine out of thirteen speakers, the consonantal merger is taking place between the aspirated and lax stop in terms of VOT. There were also intra-speaker variations on the merger in three aspects: First, is the consonantal (VOT) merger between the two stops is in progress or not? Second, are VOTs for aspirated stops getting shorter or not (i.e., the aspirated-shortening process)? Third, are VOTs for lax stops getting longer or not (i.e., the lax-lengthening process)? The results of remarkable inter-speaker and intra-speaker variability indicate a synchronous speech sound change of the stop system in contemporary Korean. Some speakers are early adopters or active propagators of sound change whereas others are not. Further study is necessary to see whether the inter-speaker differences exceed intra-speaker differences in sound change.

Keywords: voice onset time (VOT), sound change of Korean stops, consonantal merger, speaker variability

1. Introduction

All languages in the world have undergone change. One of the representative changes is sound change. It has been traditionally defined as “any appearance of a new phenomenon in the phonetic/phonological structure of a language” (Lass, 1984). More simply, sound change might be described as any particular change in the sound system of a language over a period of time. With this definition, tonogenesis in Tibetan (e.g., go < k^ho with L) is a well-known example from a diachronic perspective (Matisoff, 1973).

Sound change in a language is not only a diachronic phenomenon but also a synchronic phenomenon. During the same period of time sound system of a language may change due to various factors of the speakers. Synchronic changes deal with speaker variability. Variability is a defining characteristic of human speech. Many phonetic studies of speech has confirmed the variability of speech production across various speakers and within the same speaker on various occasions. Ohala (1993, 2012) pointed out that pronunciation variations are responsible for sound change and

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claims that instrumental phonetic studies shed light on the large amount of variation existing in speech sound articulation. Speaker characteristic differences are supposed to voice features based on the individual articulatory gestures of speaker (Johnson, 1997; Mooshammer *et al*., 2008). Speech sound articulation changes in time, both in one's life and across generations. The fact that speakers articulate speech sounds or words differently, depending on sociolinguistic factors (age, gender, dialect, and so on) and language contact was demonstrated and discussed the past decades (Weinreich, 1953; Labov, 1994, 2001; Cho *et al*., 2002; Silva, 2006; Oh, 2011). These factors might play an important role in the variability of speech production. Both inter-speaker and intra-speaker variability is an important topic in phonetics, both in speech production and speech perception (Best, 1995; Johnson, 1997; Mooshammer *et al.*, 2008). With a few exceptions, inter-speaker differences have received little attention in the phonetic studies on sound change. Inter-speaker differences are frequently treated as undesirable noise in the data or faded out by pooling or averaging over speaker groups. The present study gives more weight to individual speakers and their language background.

The Korean speech sound inventory contains an atypical consonant system in that the three Korean stops are all voiceless, traditionally described as "tense (or fortis)," "lax (or lenis)," and "aspirated" (Kim, 1965; Cho *et al*., 2002). According to Kim (1970), they are defined in terms of the amount of aspiration: "unaspirated,", "lightly aspirated," and "heavily aspirated." Arguing against the Korean stop system, in which many issues remain unsolved, Kim proposes a regular stop system: voiced, voiceless unaspirated, and voiceless aspirated (2000, 2012). Regardless of how they are phonologically defined, Korean stops are phonetically characterized by voice onset time (VOT) and fundamental frequency (f0) which have been considered as effective means to contrast the three Korean stops. On average, VOTs are shortest for Korean tense stop, longer for lax, and longest for aspirated (Lisker & Abramson, 1964; Kim, 1965, 1970; Han & Weitzman, 1970; Cho *et al*., 2002). At the same time, despite systematic mean differences, VOT values for individual tokens of lax and tense or aspirated stops overlap. On average, f0 is lowest for vowels following lax stops, higher following tense stops, and highest following aspirated (Han & Weitzman, 1970; Kim, 2000), although the f0 ranges reported for the tense and aspirated categories substantially overlap.

Recent studies have reported that aspirated and lax stops are undergoing a change in terms of VOT and f0. Lax stops lower f0 whereas aspirated stops raise f0, resulting in an onset-tone interaction of lax-Low versus aspirated-High tone (Kim, 2000; Kim *et al*., 2002; Kim & Duanmu, 2004). Besides their effect on the f0 contour of the following vowel, a partial or complete VOT merger is taking place between aspirated and lax stops because the VOT differences between the two stops are being decreased (Silva, 2006; Kang & Guion, 2008; Oh & Yang, 2013; Lee & Jongman, 2012; Kim, 2014). Because of an onset-tone interaction and the consonantal merger, f0 arises as an important acoustic parameter to distinguish aspirated from lax stops (Kim *et al*., 2002; Kim, 2014).

The extent to how much two stops are similarly produced has been shown to vary by age, gender, dialect, speech rate, and L2 proficiency. Silva (2006) discussed a robust cross-generational difference in the production of the two stops. Especially young speakers, who were born after 1965, were shown to make significantly smaller VOT differences between the two consonants while older speakers made a greater distinction. However, Kim (2008) reported that, for the Seoul speakers, some old speakers in their forties and fifties showed the merger while some young speakers even in their twenties did not show the merger. The results indicate that there are intra-speaker differences in the same generation.

Choi (2002) found dialectal variations by analyzing speakers' stop productions from two different dialects of Korean. Seoul Korean speakers had a VOT merger while Chonnam Korean speakers did not. Her data also showed some intra-speaker variations from the same Seoul speakers: out of two, one Seoul speaker alone showed a substantial VOT overlap between lax and aspirated stops (2002, p. 17). Furthermore, Cho *et al* (2002) showed the opposite pattern between Seoul and Cheju dialect. The Cheju dialect exhibited more overlap in VOT ranges than the Seoul dialect. With respect to the VOT merger, some dialects are shown to be similar to Seoul Korean whereas non-Seoul dialects such as Gyungsang and Yanbian Korean are shown to make a distinction (Oh & Yang, 2013; Lee & Jongman, 2012). The conflicting results indicate intra-speaker variations within the same dialect.

The phonetic realization of the two stops was also shown to differ by gender. Oh (2011) reported that the lax-aspirated merger was mainly observed in the speech of female speakers but not in that of male speakers. With a few exceptions, Kim (2014) also reported that the merger process was much greater for females than males. She reported intra-speaker variations in that, out of 7 speakers, one female speaker did not show any merger. In spite of some individual differences, the findings overall suggest that female speakers are more innovative than male speakers to lead a sound change. They are also in line with the sociolinguistic view of women's high level of linguistic awareness and their progressive lead in sound change (Labov, 1994). Taken the aforementioned factors together, we might say that young female speakers are the most active propagators in sound change.

With respect to the effect of speech rate, Oh (2009) reported that the merger between the two stops occurred at all speaking rates. She also found that there were large individual differences on VOT for each rate. As for the effect of L2 proficiency on L1 speech, Kim (2011) provided some evidence on VOT: for both L1 and L2 stops, the more proficient, the shorter VOTs. She reported that the merger was more robust for advanced L2 speakers than for L2 beginners. The effect were shown to be some individual differences.

The aforementioned studies overall suggest that there might be the effect of age, gender, dialect, and L2 proficiency on sound change (i.e, VOT merger). There might also be inter-speaker and intra-speaker variations for any factor. With a few exceptions, most of previous studies have mainly focused on group-normative effects, that is, effects that are representative of the population as a whole (Silva, 2006; Oh, 2009, 2011). Little attention has been paid to individual differences on sound change and the role of individuals in the actuation of sound change. Two fundamental questions regarding sound change in present-day Korean arise: (i) whether the sound change holds for across individual speakers, and (ii) whether the inter-speaker and intra-speaker differences in the pronunciation of the stops are really so large as to support the claim that the articulatory gestures are internally changing. If we can confirm that acoustic variability occurring both among different speakers and within the same speaker in the articulation of the stops, this could be regarded as the ongoing progress of a speech sound change. Our hypothesis is that there is a synchronous change taking place in the articulation of the aspirated and lax stop in Korean. We suppose that there will be certain patterns even for speaker variations on sound change.

The current study replicated Kim's (2014) experiment on VOT with different Seoul speakers. The study further examines whether the sound change holds for not only group speakers but also across individual speakers. In methodology, when recruiting participants, socio-phonetic factors such as age, gender, dialect, L2 exposure period, and speech rate were controlled to minimize established effects on VOT. Furthermore, on the assumption that there will be inter-speaker and intra-speaker variability on sound change, the production of Korean stops by native Seoul Korean speakers was analyzed and compared the individual results with the pooled results.

2. Method

2.1. Participants

Thirteen native Korean speakers (five males and eight females) participated. At the time of testing, they all had resided in Eugene, Oregon approximately for less than three months (Mean length of residence in the USA (LOR) = 2.5 months). They were all university students at a college located in the Eugene County. The mean age was 32 years, 5 months and the individuals ranged from 20 years, 6 months to 37 years, 2 months. Since they were born and had grown up in Seoul, all participants were purely native Seoul Korean speakers and used the standard dialect of Seoul Korean (i.e., 서울 토박이). They all had some knowledge of English and reported an average of 3 hours per day talking with friends in English. All of them had learned English after their puberty but they mainly use Korean on a daily basis. They reported in the self-questionnaire that they were real beginners and had problems in communicating with native speakers of English with confidence. No speakers had any history of speech pathology or phonetic training.

2.2. Speech materials

The same speech materials as in Kim (2014) were used in this study. Eighteen monosyllabic words in Korean were constructed with a balanced list of the three stop types (lax, aspirated, and tense) and the three places of articulations (labial, alveolar, and velar) followed by a vowel /a/ context. The syllable type was either CV or CVC where the final coda was /t/ or /k/ (a neutralized unreleased stop). All words were real words, as presented in <Table 1>.

Table 1. Monosyllabic words in Korean

Type	Stops	Bilabial	Alveolar	Velar
CV(C)	Asp.	[p^h^at] 'red bean' [p^h^a] 'to dig'	[t^h^at] 'blame' [t^h^a] 'to ride'	[k^h^at] 'stop' [k^h^a] 'car'
	Lax	[pat] 'field' [pa] 'to see'	[tat] 'anchor' [ta] 'all'	[kat] 'hat' [ka] 'to go'
	Tense	[p*ak] 'head' [p*a] 'to grind'	[t*ak] 'precisely' [t*a] 'to pick'	[k*ak] 'croak' [k*a] 'to peel'

(Tense stops = /p* t* k*/, lax or lenis = /p t k/, and aspirated = /$p^ht^hk^h$/)

In order to record the target words in a constant prosodic environment, they were recorded in the carrier sentence [igə ______ *hasɛjo*] "Say this ______" where the words were located in phrase -initial position. In the position, the target words were expected to be fully stressed and emphasized. Speech materials were presented in *Hangul*, the writing system of Korean.

2.3. Procedure

All speech data were collected in Eugene, Oregon in the United States. Participants were recruited only when they met the following criteria:

-ones who had lived in Eugene for less than three months (LOR)
-ones who were in their twenties or thirties (age)
-ones who were born and had grown up in Seoul (dialect)
-ones who had never lived in a non-English speaking country

Prior to recording, all of participants were asked to fill out their language background questionnaire and had a five-minute interview to answer their language background questions. Recordings were made in a sound-attenuated booth in the Phonetics Lab using a Shure (model SM 10A) head-mounted microphone and a Marantz digital recorder (PMD 670) at a sampling rate of 44,100 Hz. Each speaker was asked to read the words on the monitor in a natural intonation. The monitor connected to the computer was inside the lab but the computer itself was outside the lab to minimize background noise. The words were automatically popped up at a 3-second interval. This makes speech rate control by using the frame sentence and limiting the speakers' production time of sentences to a fixed 3 sec. A total of 936 tokens (18 words x 4 repetitions x 13 speakers) were obtained for analysis. All recorded utterances were analyzed using Praat 5.3.32, a speech analysis program (Boersma & Weenink, 2012).

VOT was measured from the release burst of a stop to the onset of periodicity in the waveform (Lisker & Abramson, 1964). The onset of the vowel in the waveform was determined by the onset of the first full glottal pulse of the vowel as well as the pitch of the spectrogram. The onset of the voicing energy in the second formant shown in a time-locked spectrogram was used to help determine voicing onset in conjunction with the waveform. The onset of voicing (= vowel onset) was defined as the first and periodic pulse of a vocalic waveform that show features typical of a vowel.

The acoustic data obtained were statistically tested using repeated measures analysis of variance (RM ANOVA) in the context of a univariate context of a general linear model (SPSS/PASW, 2012). The main goal of the present study was to examine whether there is any main effect of stop type (i.e., aspirated, lax, and tense), place (labial, alveolar, and velar), gender (male vs. female), and speaker on VOT and whether there was any interaction effect between factors. Repeated measures ANOVA includes both "between" subjects effects (gender and speaker) and "within" subject effects (i.e., stop type, place). Their main and interaction effects were statistically analyzed at a 0.05 significant level. Post hoc tests were also run to answer the following questions: (i) whether any differences in pairs among three stop types, between gender and places were significant and (ii) whether any differences in pairs among individual speakers were significant. For statistical analysis, the VOT differences and speaker variability on sound change according to the three stop types were mainly focused because of most central interest in the present paper.

3. Results

3.1. The group data

The results of univariate repeated measures (RM) ANOVA showed a main effect of stop on VOT [$F(2,819) = 3480.730$, $p < .001$] in that mean VOT values were significantly longest (79 ms) for the aspirated stop, longer (69 ms) for the lax stop, and shortest (13 ms) for the tense stop (tense < lax < aspirated). Post hoc Tukey HSD multiple comparisons revealed that differences in each pair among the three stop types were statistically significant ($p < .001$). Although they statistically differed in terms of VOT, their VOT values were largely overlapped in the range between the aspirated and lax stop, as clearly illustrated in the figure below.

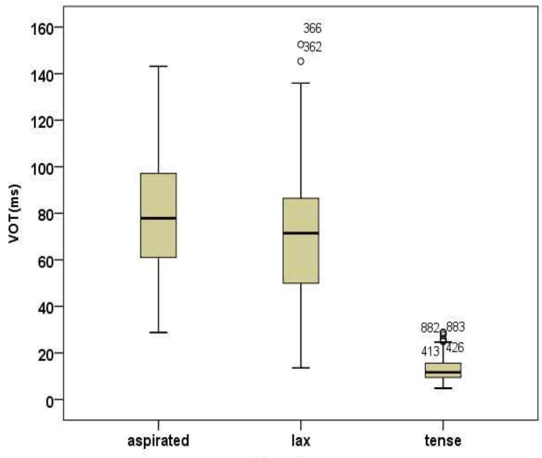

Figure 1. Mean VOT values of the aspirated, lax, and tense stop for the productions of 13 speakers (5 males and 8 females). Error bar indicates ±1 standard deviation.

As expected, there was a main effect of place of articulation on VOT [$F(2,819) = 112.355$, $p < .001$] in that mean VOT values were significantly longest (61 ms) for the velar stop, intermediate (52 ms) for the alveolar stop, and shortest (48 ms) for the labial stop (labial<alveolar<velar). There was also an interaction between stop type and place of articulation [$F(4,819) = 5.321$, $p < .001$]. The effect of stop held for across the places of articulation. For each place of articulation, mean VOT values were longest for the aspirated, longer for the lax stop, and shortest for the tense stop.

There was also a main effect of gender on VOT [$F(1,819) = 85.156$, $p < .001$] and an interaction between stop and gender [$F(2,819) = 85.156$, $p < .001$] in that mean VOTs for both aspirated and lax stops were significantly longer for male speakers than female speakers. The effect of stops for male speakers in the current study does not correspond to previous findings in Oh (2011) and Kim (2014) in which it is much weaker for males than for females. As clearly illustrated <Figure 2>, the merger between aspirated and lax stops is robust for both male and females.

Overall, the group-normative data showed that, despite systematic mean differences among the three stops in statistics, VOT differences between lax and aspirated stops are largely decreased toward the merger of the two stops. Tense stops are distinguished well from either aspirated or lax stops whereas aspirated stops are not well-distinguished from lax stops. Tense stops are realized with short-lag voicing (M_{tense} = 13 ms (10 min. ~ 15 max.)) while aspirated and lax stops both are realized with long-lag voicing (M_{asp} = 79 ms (29 min. ~ 143 max.); M_{lax} = 69 ms (14 min. ~ 153 max.)). There was an apparent VOT merger between aspirated and lax stops. With respect to the VOT merger as evidence of sound change, the current findings for the group data corresponded to findings in Silva (2006), Kang & Guion (2008), Oh (2011), Oh & Yang (2013), Lee & Jongman (2012), and Kim (2014).

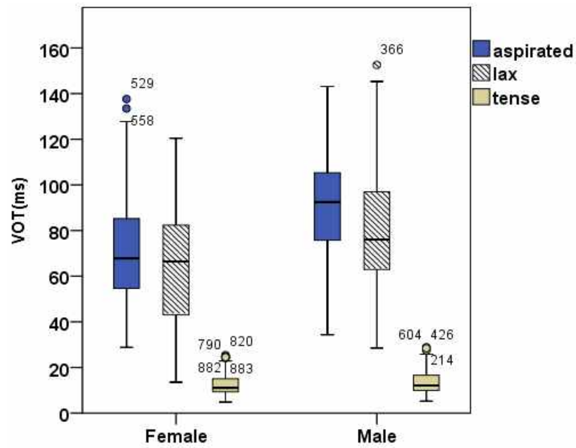

Figure 2. Mean VOTs (ms) of each stop type for the productions of female and male speakers. Error bar indicates ±1 standard deviation.

3.2. The individual data

<Figure 3> shows the individual VOT plots of the three stops. Statistical analysis confirmed significant differences among speakers [$F(11,819) = 102.315$, $p < .001$] and an interaction between stop and individual [$F(22,819) = 36.698$, $p < .001$] in that individual speakers produced the three stops differently in VOT. There are remarkable individual differences on VOT in producing aspirated and/or lax stops. With some speakers, e.g., F4, F5, M1, M3, M5, VOTs are much longer for aspirated and/or lax stops than with others. Most of speakers but a few showed a near-merger between the two stops, as illustrated in the figure below.

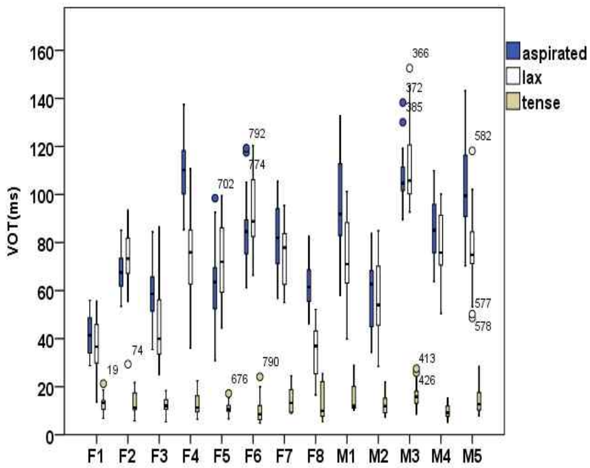

Figure 3. Mean VOT values of each stop type for the productions of individual speakers. Error bar indicates ±1 standard deviation.

In order to capture VOTs in detail, mean VOTs, their ranges, and the $VOT_{asp=lax}$ merger are presented in <Table 2>. The merger indicates that VOT differences between the two stops were not significantly different ($p > 0.05$).

Table 2. Mean VOTs and their range for individual speakers

Spkr.	$VOT_{aspirated}$	VOT_{lax}	$VOT_{asp\text{-}lax}$	Merger
YHK(F1)	42(29~56)	37(14~56)	5	YES
MJK(F2)	68(53~85)	73(29~94)	-5	YES
AYK(F3)	58(35~85)	46(29~56)	12	YES
MHP(F4)	110(85~138)	75(36~111)	35	NO
YHS(F5)	62(31~99)	71(45~100)	-9	YES
SNC(F6)	85(61~119)	92(67~121)	-7	YES
MYH(F7)	83(57~106)	75(55~96)	8	YES
HRH(F8)	63(46~83)	36(17~52)	27	NO
SHK(M1)	96(58~133)	73(40~101)	23	NO
JHK(M2)	59(34~84)	57(29~85)	2	YES
TWK(M3)	108(90~138)	112(93~153)	-4	YES
HJK(M4)	85(64~110)	78(51~100)	5	YES
JHP(M5)	104(70~143)	77(49~118)	27	NO
Mean	***79(29~143)***	***69(14~153)***		

Taking the individual data into consideration, there is huge inter-speaker variability as well as intra-speaker variability on VOT, indicating that the sound is internally changing from speaker to speaker. Individual speakers are different in the following three aspects. First, is the aspirated-lax merger as evidence of sound change in progress or not? Speakers roughly show three different patterns: *no merger, partial merger, and complete merger*. The *no merger* pattern corresponds to the traditional pattern with a three-way categorization on VOT, as reported in previous findings. The pattern is clearly observed from speaker F8 ($M_{aspirated}$ = 63 ms, M_{lax} = 36 ms, and M_{tense} =10 ms) and others (F4, M1, M5). Since the three stops are distinguished by VOT, they can be called "conservative speakers" in sound change. The *partial* or *complete merger* patterns correspond to the innovative pattern with a two-way categorization between short-lag and long-lag voicing because of the VOT merger between aspirated and lax stops. The pattern is observed from nine out of thirteen speakers. For example, speaker M1 shows a near merger pattern ($M_{aspirated}$ = 96 ms and M_{lax} = 73 ms) and speaker M4 a complete merger ($M_{aspirated}$ = 85 ms and M_{lax} = 78 ms). Four out of nine speakers, who show the complete merger, are radical innovators in sound change because their VOT values for lax stops are even much longer than those for aspirated stops (e.g., F2, F5, F6, M3). Secondly, are VOTs for aspirated stops getting shorter or not? In comparison to Lisker & Abramson's (1964) VOT values ($M_{aspirated}$ = 103 ms), six speakers' VOT values are much shorter than others. In contrast, speakers M5, F4, M1, and M3 maintain long VOTs similar to Lisker & Abramson's (1964). Interestingly, they also have very long voicing lags even for lax stops. It seems that, once a speaker has a long VOT for the aspirated stop, he or she also carries a similar long VOT for the lax stop as well or vice versa. Thirdly, are VOTs for lax stops getting longer or not? Compared with Lisker & Abramson's (1964) VOT values (M_{lax} = 30 ms), most of speakers except for the two speakers, e.g., F1 and F8, have relatively long VOTs for lax stops, as presented in <Table 2>. The two speakers' VOTs for aspirated stops are also short and similar to those of the lax stop. For individual speakers, it is very common to have both aspirated and lax stops in a similar pattern in VOT duration. Once the aspirated stop remains long, the lax stop is also long and vice versa. This indicates that, for some speakers, the sound change seems to occur in either directions: the aspirated-shortening and/or lax-lengthening. It also suggests that VOTs for the production of stops are internally changing for each speaker. Hence, individual speakers play an important role in taking a part in sound change.

For individual speakers, the sound change toward the merger is ongoing: either a shortening process or a lengthening process, as clearly illustrated in the figure below. The term *shortening* can be applied for speakers who have much shorter mean VOT than the group mean. The term *lengthening* can be applied for speakers who have longer mean VOT than the group mean. The processes of shortening and/or lengthening among individual speakers are clearly illustrated in <Figure 4>.

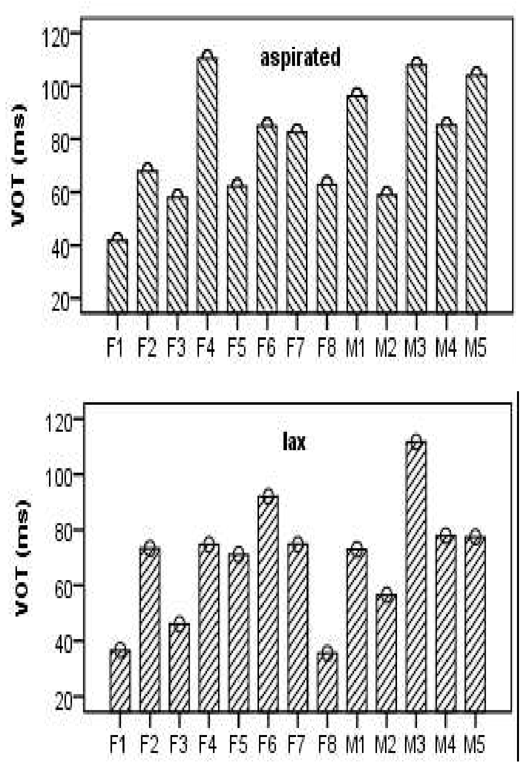

Figure 4. Mean VOT values of the aspirated and lax stop for the productions of individual female (F) and male (M) speakers.

Taking group mean VOTs as a reference point in consideration, six out of thirteen speakers show a shortening process on VOT for the aspirated stop. With speakers, e.g., F1, F2, F3, F5, F8, and M2, VOTs for the aspirated stop are shorter (i.e., below group mean 79 ms) than others, indicating a shortening process of VOTs. The detailed data of the Tukey post-hoc tests show that there were five statistical groupings among speakers. There is also a lengthening process for the lax stop. Nine out of thirteen speakers produced lax stops with relatively longer VOTs (above group mean 69 ms). There were five statistical subsets among speakers, as presented in (1).

(1) Five statistical subsets for the production of lax stops
Group 1: speakers F1, F3 and F8 (36ms ~ 46ms)
Group 2: speaker M2 (57 ms)
Group 3: speakers F2, F4, F5, F7, M1, M4, and M5 (71ms~78ms)
Group 4: speaker F6 (92ms)
Group 5: speaker M3 (112ms).

Remarkable inter-speaker differences show some gender dependency. Similar to Oh's (2011) and Kim's (2014) findings, female speakers tend to show more merger than male speakers. However, three out of five show the merger for male speakers and five out of eight show the merger for female speakers. This indicates that the effect of gender on VOT for the males are similar to that for females. However, there are intra-speaker variations within the same gender. Let us compare speaker JHK(M2) with speaker TWK(M3) for the plots of aspirated and lax stops, as illustrated in <Figure 5>.

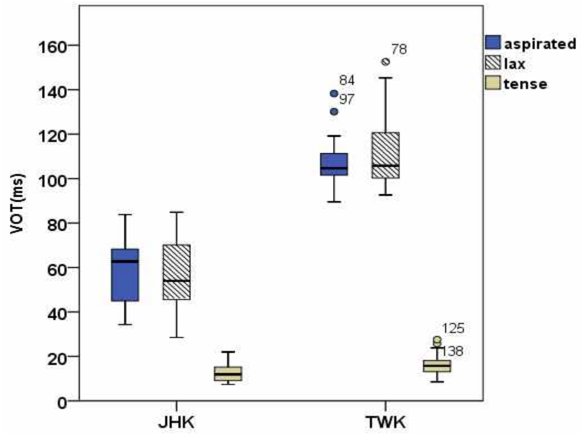

Figure 5. Mean VOT values of each stop for speaker JHK(M2) and TWK(M3). Error bar indicates ±1 standard deviation.

They both were male speakers (same gender), in their twenties (23 vs. 20) and they grew up in Seoul (i.e., same dialect). In addition, they had lived in the USA for no more than 2 months (similar L2 exposure). In spite of their similar language background, their VOT values for aspirated and lax stops are similar in one hand but different in the other hand. In <Figure 5>, the two speakers' pattern are very similar in that they both show the complete merger on VOT between the two stops. However, they are very different in VOT duration. Speaker TWK's VOT values for both aspirated and lax stops are twice as long as those of speaker JHK ($M_{aspirated}$ = 108 ms and M_{lax} = 112 ms vs. $M_{aspirated}$ = 59 ms and M_{lax} = 57 ms). Toward the merger, a shortening process for aspirated stops is undergoing for speaker JHK while a lengthening process for lax stops is undergoing for speaker TWK. Either way results in a merger.

When aspirated stops are getting shorter and/or lax stops are getting longer, we can say that they are changing as diachronic evidence of sound change. Concerning this, one question arises: Can the merger occur without this process? The answer is *No*. The merger is possible only when either process occurs. For speaker F5, both processes had already occurred. The aspirated-shortening process is observed for speaker F1 and M1. In contrast, the lax-lengthening process is observed for most of speakers F2, F6, F7, M1, M3, and M4. Note that speaker TWK (M3) had relatively longer VOTs for both aspirated and lax stops (108 ms for the aspirated and 112 for the lax stop) than others. His VOT differences between the two stops were not statistically significant, indicating that there was a merger. Similar to TWK, speaker JHP (M5) also had a quite long range of VOT for aspirated stops ($M_{aspirated}$ = 104 ms) as well as lax stops (M_{lax} = 77 ms). Unlike TWK, he shows a three-way or no merger pattern. Although male speaker HJK and JHK both had a relatively shorter VOTs than TWK and JHP, speaker JHK had the merger but HJK did not. This is similar to female speakers' productions. Among seven speakers, speakers YHK(F1), AYK(F3), and HRH(F8) relatively shorter VOTs for both stops than others. Speaker AYK and YHK had a merger but speaker HRH did not. For speaker YHK, both merger and shortening have occurred. Speaker MHP(F4) and SNC(F6) had relatively longer VOTs for both stops than others. Speaker SNC showed a merger whereas speaker MHP did not. For speaker MHP, however, neither merger nor shortening has occurred.

Considering all the individual data, inter-speaker and intra-speaker differences are shown to be spectacular. The within-speaker variability in females appears to be high. Note that speakers employed in the present study were from the same Seoul dialects and the same generations in their twenties and thirties. In addition, their LOR was similar and speech rate was also controlled. Despite the fact that such socio-phonetic factors as age, dialect, LOR, and even speech rate were controlled, there were huge inter-speaker and intra-speaker variations on the merger and duration, indicating a synchronous speech sound change.

4. Discussion

The current study investigated the VOT productions of the three Korean stops based on speech materials of 13 Korean adults with similar L2 exposure. Replicating Kim's (2014) experiment with different speakers, this study focused on the inter-speaker and intra-speaker variability on sound change in contemporary Seoul Korean. The group-normative results showed that mean VOT values were significantly longest (79 ms) for the aspirated stop, longer (69 ms) for the lax stop, and shortest (13 ms) for the tense stop (tense < lax < aspirated) (<Figure 1>). The statistical analysis on the group data supports that the three Korean stops are well distinguished from each other in terms of VOT, corresponding to previous findings (Lisker & Abramson, 1964; Kim, 1970; Han & Weitzman, 1971; Cho *et al*., 2002). As a piece of diachronic evidence of a sound change, the present findings are comparable to those of Lisker & Abramson's (1964) in that mean VOT values for aspirated stops are getting much shorter (M_{asp} = 103 ms to 79 ms) whereas mean VOT values for lax stops are in contrast getting much longer (M_{lax} = 30 ms to 69 ms). As a result of the shortening and lengthening process in either way, it is clear that Seoul speakers are participating in changing their pronunciation for aspirated and lax stops. However, the sound change is not taking place in every individual. As clearly illustrated in <Figure 3>, some speakers are shown to maintain the traditional pattern while others are shown to change their pronunciations. For the individual data, individual speakers pronounce stops in three different ways: First, are VOTs for the aspirated stop getting shorter or not (i.e., the aspirated-shortening process)? For some speakers, aspirated stops tend to decrease the amount of aspiration. Secondly, are VOTs for the lax stop getting longer or not (i.e., the lax-lengthening process)? For some speakers, lax stops tend to increase the amount of aspiration. Thirdly, is the merger as synchronic evidence of sound change ongoing or not? The ongoing processes of shortening or lengthening results in the merging of aspirated and lax stops. Some speakers show either process while others do not (see <Figure 4>).

The findings that inter-speaker differences show some gender dependency is worth discussing. Female speakers tend to show more merger than male speakers, corresponding to previous findings (Oh, 2011; Kim, 2014). However, the present results show that the effect of gender on VOT for the males are very similar to that for females. There are also intra-speaker variations within the same gender (see <Figure 5>). There is evidence that women take a leading role in sound change (Labov, 1994). Obviously, gender itself should not have an effect on sound change, but sometimes the gender of speakers who influence a sound change might be important. Based on the data obtained in this study, female speakers produce the aspirated and lax stop with large VOT overlap. This study supported the leading role of women in a sound change. However, since even within the same generation and gender, there were intra-speaker variations on VOT (Kim, 2008, 2014), further research is needed before making universal claim.

In the current study, socio-phonetic factors such as age, dialect, gender, LOR, and speech rate that might influence VOT were controlled to minimize any possible effects. Even with controlled speakers' language background, some speakers made a clear lax and aspirated distinction whereas others showed the VOT merger of the two stops. Some speakers had relatively longer VOTs for both stops than others. Remarkable inter-speaker and intra-speaker variability suggest that speakers themselves are internally changing their pronunciations. Thus, some speakers are early adopters or more active propagators of sound change than others. In addition, inter-speaker and intra-speaker variability indicate that a synchronous speech sound change is in progress in the stop system of Korean. Although there are various (methodological) difficulties in comparing the present data to those published in the literature decades ago, there can be no question that a synchronous change in the articulation of the lax and aspirated stop is in progress. Taken the previous findings of socio-factors together, we might say that young female Seoul speakers are the most active initiators and propagators in sound change.

The current study has an implication that a change is going on the articulation of the aspirated and lax stop in contemporary Korean. As expected, great variability was found among individual speakers and more importantly intra-speaker variability is shown to be essentially as great as the inter-speaker variability. One question arises how and why a speaker chooses the direction of sound change in terms of VOT duration (short to long, long to short). As can be seen in <Figure 4>, six out of thirteen choose a VOT shortening for aspirated stops whereas nine speakers choose a VOT lengthening for lax stops. The change may be a result of combined influences from internal and external factors.

One of the great mysteries of linguistics is the so-called actuation problem, that is, what causes the inception of language change. Starting with Weinreich's classic book *Languages in Contact* (1953), research over the past half-century has brought about a recognition of the importance of language contact for explanations of many linguistic changes. One might say that aspirated stops in Korean are getting shorter because of the language contact (Kim, 2011). If language contact may be the one that initiates the sound change in Korean, further analyses of the effect of English on VOT are needed to find answers to this question.

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