

Dialect and Gender Variations in the Place and Manner of Articulation of the Korean Fricatives

Kyung-Im Han

Abstract—This study examines dialect and gender variations in the place and manner of articulation between the two Korean fricatives, /s/ and /s'/, as produced by speakers of the Daegu and Jeju dialects. The acoustic parameters of center of gravity and skewness for the place of articulation, and the rise time and the amplitude rise slope for the manner of articulation were measured. The study results revealed a gender effect, but no dialect effect, for the center of gravity and the skewness. No main effect for either the gender or dialect was found for the rise time and the amplitude rise slope. These findings indicated that, with regard to the place of articulation, Korean fricative sound differences are a gender distinction, not a dialectal one.

Keywords—Dialect, gender, Korean fricative, manner of articulation, place of articulation, spectral moments.

I. INTRODUCTION

WHEN we pronounce a sound, we use one or more articulators. Regardless of speakers' demographic information such as region, gender, or age, they all use the same articulators to produce the same sound. For example, the consonant /p/ is produced with the upper and lower lips, and the vowel /i/ is produced by raising the tongue tip and placing it near the alveolar ridge. Although every speaker makes a certain sound with the same articulators, the sound produced is somewhat differently perceived by a hearer in terms of the quality of the sound. One question that may be asked is, what accounts for these sound differences? Are they due to dialectal or gender differences between speakers? Or do they occur because an articulated sound varies as a function of the place or manner of articulation, or both? In order to address these questions, the present study investigates the effect of dialect and gender variation on the two Korean fricatives /s/ and /s'/' as produced by speakers of the Daegu and Jeju dialects, and investigates whether these sound variations differ according to fricative placement and manner of articulation.

According to the definition of fricatives by Stevens [1], "fricatives are produced through a very narrow constriction in the oral cavity, creating turbulence in the flow through the constriction, and the acoustic properties of fricatives are characterized as the noise of a sound on the spectrogram, and the spectral properties of the friction noise are determined by the shape and the position of the tongue." Since the noise spectrogram of fricatives is affected by the length of the front cavity depending on the constriction of the front part of the tongue blade, it has been generally accepted that the location of this noise spectrum is a cue to place of articulation [2]. One of

the most commonly used methods for analyzing the spectral properties of friction noise to identify for a fricative's place of articulation is a spectral moment analysis [3]-[6]. The spectral moment analysis represents both local and global information of the spectrum [4]. As for the manner-related acoustic parameters: silence duration [7], [8], [10], friction duration [9], rise time [10], amplitude rise slope [11], [12], F2 transition [7], [13], and release burst [10], they are considered to be robust cues to manner of articulation regarding fricative and affricate sounds.

Using the center of gravity and skewness for the place of articulation, and the rise time and the amplitude rise slope for the manner of articulation as the acoustic parameters, this study explores whether these same acoustic parameters vary as a function of dialect (Daegu vs. Jeju), and gender (male vs. female) in terms of place and manner of articulation. The findings of this study are discussed from sociophonetic viewpoints.

II. METHODOLOGY

A. Participants

Twenty-eight speakers (14 males and 14 females) aged between 20 years and 30 years, of both Daegu and Jeju dialects, were recruited for this study. Each group consisted of the same number of male and female speakers. Participants reported normal speaking and hearing and had no history of speech disorders. They volunteered for the experiment without any compensation.

B. Speech Materials

The six words chosen for the study were real, two-syllable words. The words used for the study were 'sidae, sakwa, sudo, s'ilim, s'aim, s'ukin.' The speech material for this study consisted of disyllabic words of the form /C₁V\$C₂V(C)/ where C₁ is the fricative /s/ or /s'/, and C₂ is any consonant, and V is /i, a, u/. The participants were asked to pronounce each word three times in the carrier sentences 'itanənin _____ ipnita (This word is _____.)' In total, 504 tokens (6 words × 3 repetitions × 14 participants) were analyzed for the study.

C. Acoustic and Statistical Analysis

Recordings were made in a very quiet room using a SAMSON microphone and a desktop computer that ran the PRAAT speech analysis software program [14]. The microphone was placed in front of the computer, approximately 10 cm away from the participants' lips. The speech tokens were sampled at a rate of 44.1 kHz. Before recording, the participants were asked to practice reading the list of words as naturally as

possible at the normal speed in order to familiarize themselves with this procedure.

For the acoustic analysis, four acoustic parameters were measured: the center of gravity, skewness, rise slope, and amplitude rise slope. The acoustic measurements were taken on both the spectrogram and the waveform. The center of gravity and skewness were the acoustic indicators for the place of articulation, and rise time and amplitude rise slope were the indicators for manner of articulation. The center of gravity and skewness were obtained automatically by the PRAAT from the frequency spectrum of the fricatives by FFT taken from a 20-ms Hamming window at the midpoint of the fricative noise in the fricatives. Rise time was identified using Castleman's method [9], by measuring from the time of frication onset to the time of maximum amplitude rise on the spectrogram. For the measurement of the amplitude rise slope, the frication parts of each sound were divided into three 10-ms frames in the initial, medial, and final parts of the sound, and then the amplitude for each frame was computed. In order to calculate the amplitude rise slope, the Microsoft Excel Slope Function was used. In order to determine whether the obtained values for each acoustic parameter were significantly different as a function of fricative category, dialect, vowel context, or gender, the SPSS statistical software package for Windows (version 23.0) was used. A statistical significance level was set at 0.05 for all tests.

III. RESULTS AND DISCUSSION

The acoustic parameters investigated for fricative sounds in this study were center of gravity and skewness for the place of articulation, and rise time and rise slope for the manner of articulation¹. The results involving each parameter of the two Korean fricative sounds /s/ and /s'/ are reported in the following sections.

A. Center of Gravity

Table I represents the mean center of gravity values from the Korean fricatives /s/ and /s'/ in terms of dialect, vowel context, and gender.

A three-way ANOVA (dialect×gender×vowel context) using center of gravity as the dependent variable revealed that for the /s/ a main effect was found ($[F(1,72)=4.560, p<0.05]$). This indicates that Daegu speakers (7800.7 Hz) had a significantly greater value than Jeju speakers (7191.3 Hz). It is accounted for by the correlation between the frontedness of constriction and the center of gravity, indicating that Daegu speakers pronounced the /s/ with a more fronted tongue articulation than Jeju speakers. No main effect of dialect was found for the /s'/, however. For gender, a main effect was observed on the /s/ and /s'/ . For the /s/ (6707.0 Hz vs. 8284.9 Hz for males and females, respectively) and /s'/ (7278.3 Hz vs. 8595.8 Hz for males and females, respectively), female speakers had a significantly higher center of gravity regardless of fricative category. This implies that female speakers tend to produce fricative sounds

¹ The data used for the manner of articulation in this study are a part of the acoustic analysis data presented in the paper entitled "Speaker and Vowel Variability in Manner of Fricatives and Affricates in Korean" (2017) by the author [15].

with a greater frontedness of constriction than males, regardless of dialect. Figs. 1 and 2 represent the mean center of gravity of the fricatives /s/ and /s'/ according to dialect and gender, respectively.

TABLE I
MEAN CENTER OF GRAVITY OF THE KOREAN FRICATIVES /s/ AND /s'/,
GROUPED AS A FUNCTION OF DIALECT, VOWEL CONTEXT, AND GENDER

| Consonant Phonation Type | Acoustic Parameter | Dialect | Vowel context | Gender | |
|-----------------------------|-----------------------|---------|------------------|------------|----------------|
| | | | | Male | Female |
| /s/ | Center of gravity | Daegu | /i/ | 5032.6 | 7286.1 |
| | | | /a/ | 6619.3 | 8228.1 |
| | | | /u/ | 6749.9 | 9231.6 |
| | | | Average | 6133.9 | 8248.6 |
| | | | /i/ | 5953.6 | 6528.1 |
| | | Jeju | /a/ | 8108.0 | 9465.9 |
| | | | /u/ | 7779.0 | 8969.7 |
| | | | Average | 7280.2 | 8321.2 |
| | | | significance | $p<0.05^*$ | $p<0.001^{**}$ |
| | | | | | $p<0.001^{**}$ |
| /s'/ | Center of gravity | Daegu | /i/ | 5032.6 | 7286.1 |
| | | | /a/ | 6619.3 | 8228.1 |
| | | | /u/ | 6749.9 | 9231.6 |
| | | | Average | 6133.9 | 8248.6 |
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Note: $p<0.05^*$, $p<0.001^{**}$

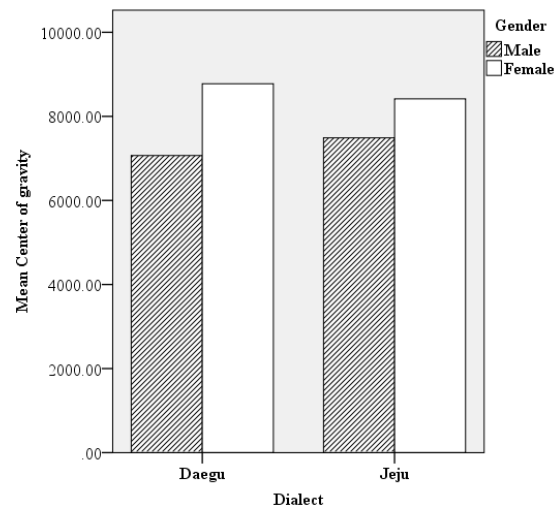


Fig. 1 Mean center of gravity of the /s/ as a function of dialect and gender

The difference between male and female speakers on the mean values for center of gravity may be accounted for by two well-known hypotheses. One hypothesis is that this difference may be due to the anatomical variation in vocal tract length from the vocal cord to the lips between the two genders. The mean vocal tract length for males is 6.6 inches, but for females it is 5.5 inches [16]. Since the female vocal tract is shorter than the male, the females' short vocal tract length results in higher resonant frequencies.

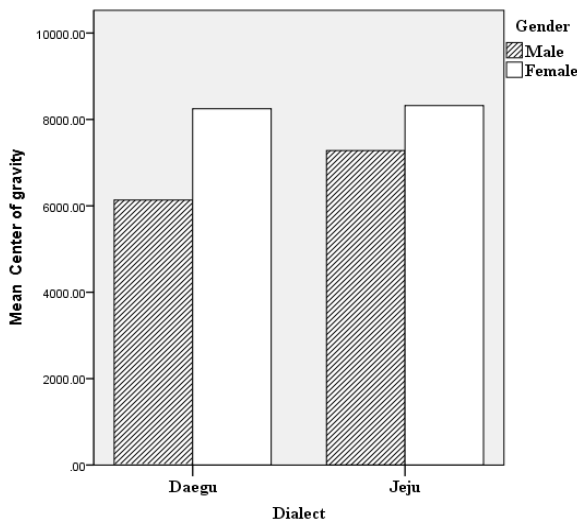


Fig. 2 Mean center of gravity of the /s/ as a function of dialect and gender

The other hypothesis is that since vocal tract length is related only with the back of the cavity, the front part of the oral cavity does not affect the whole length of vocal tract. In this regard, the higher center of gravity value of female speakers may be accounted for by socially constructed cultural norms and not by the vocal tract length difference [17], [18]. Strand [17] and Docherty [18] proposed that men and women employ different strategies to express their masculinity or femininity as a social-indexical marker in their speech community when pronouncing the /s/, and as a result, social-indexical information is reflected in their articulated speech as well as in other linguistic information. From these two perspectives, it is hard to conclude which hypothesis, either anatomical features or social-indexical marker, is correct. In order to identify which hypothesis is more plausible in accounting for the phenomenon of the female speakers' frontedness, a study targeting speakers of different age groups should be conducted.

A main effect of vowel context was also found for both fricative sounds. For the /s/ ([F(2,72)=20.642, $p<0.001$]), the mean of center of gravity preceding /i/ was 6200.1 Hz, preceding /a/ was 8105.3 Hz, and preceding /u/ was 8182.5 Hz. For the /s'/ ([F(2,72)=48.766, $p<0.001$]), the mean of center of gravity preceding /i/ was 5923.3 Hz, preceding /a/ was 9399.0 Hz, and preceding /u/ was 8488.6 Hz. Further, Tukey HSD post hoc tests for the two sounds showed that the mean values for the back vowels /u/ and /a/ were higher than for the front vowel /i/. This result supported the assertion by Shadle and Mair [19] that the constriction position of fricatives varies as a function of vowel context, showing that the place of articulation for the Korean fricatives /s/ and /s'/ before the back vowels /u/ and /a/ moves forwards compared to that before the front vowel /i/.

As for the interaction between two factors, only a dialect \times vowel interaction was found for the /s'/ ([F(1,72)=5.634, $p<0.05$]), and not for the /s/. For the Daegu and Jeju speakers, the mean center of gravity preceding /i/ was 6560.6 Hz and 5286.0 Hz, preceding /u/ was 7911.1 Hz, and 9066.6 Hz, and

preceding /a/ was 9291.9 Hz and 9506.1 Hz, respectively. That is, these findings showed that the constriction position of fricatives differs according to the vowels followed by the /s/ and /s'/.

B. Skewness

Table II represents the mean skewness values from the Korean fricatives /s/ and /s'/ in terms of dialect, fricative category, vowel context, and gender.

TABLE II
MEAN SKEWNESS OF THE KOREAN FRICATIVES /s/ AND /s'/, GROUPED AS A FUNCTION OF DIALECT, VOWEL CONTEXT, AND GENDER

| Consonant Phonation Type | Acoustic Parameters | Dialect | Vowel context | Gender | |
|--------------------------|---------------------|---------|---------------|--------------|----------------|
| | | | | Male | Female |
| /s/ | Skewness | Daegu | /i/ | 1.16 | 0.00 |
| | | | /a/ | -0.11 | -0.73 |
| | | | /u/ | 0.07 | -0.60 |
| | | | Average | 0.37 | -0.44 |
| | | | significance | $p>0.05$ | $p<0.001^{**}$ |
| | | Jeju | /i/ | 0.78 | 0.57 |
| | | | /a/ | -0.31 | -0.94 |
| | | | /u/ | -0.24 | -0.56 |
| | | | Average | 0.08 | -0.31 |
| | | | significance | $p<0.05^{*}$ | $p<0.001^{**}$ |
| /s'/ | Skewness | Daegu | /i/ | 1.11 | 0.27 |
| | | | /a/ | -0.67 | -1.23 |
| | | | /u/ | -0.28 | -0.85 |
| | | | Average | 0.05 | -0.60 |
| | | | significance | $p<0.05^{*}$ | $p<0.001^{**}$ |
| | | Jeju | /i/ | 1.51 | 1.10 |
| | | | /a/ | -0.62 | -0.47 |
| | | | /u/ | 0.07 | -0.47 |
| | | | Average | 0.32 | 0.05 |
| | | | significance | $p<0.05^{*}$ | $p<0.001^{**}$ |

Note: $p<0.05^{*}$, $p<0.001^{**}$

A three-way ANOVA (dialect \times gender \times vowel context) with the skewness as the dependent variable revealed that a main effect of dialect was found ([F(1,72)=1.931, $p<0.05$]) for the /s'/, indicating that skewness for Daegu speakers was significantly higher than for Jeju speakers, indicating that Daegu speakers pronounced the /s'/ with a stronger concentration of energy in the lower frequencies than Jeju speakers. However, no main effect of dialect on the /s/ for skewness was found. In addition, a main effect of gender was observed for both fricatives, /s/ ([F(1,72)=13.608, $p<0.001$]) and the /s'/ ([F(1,72)=5.944, $p<0.05$]), showing that the fricatives /s/ and /s'/ produced by female speakers had significantly lower skewness values than those produced by males. This result demonstrated that compared to the male speakers, females pronounced the /s/ and /s'/ with a strong concentration of energy in the higher frequencies with a lesser spectral tilt, and further, supported the claim by Jongman et al. [5] that female speakers' skewness values were significantly lower than those of males.

A main effect of vowel was also obtained for skewness ([F(2,144)=50.529, $p<0.001$]). The skewness values of the fricative productions varied significantly as a function of vowel context. That is, the skewness preceding /i/ was 0.81, /a/ was -0.64, and /u/ was -0.36, and Tukey HSD *post hoc* tests indicated that skewness values were higher for the front vowel /i/ than for the non-front vowels /u/ and /a/. This study's results supported the proposal by Hwang [20], suggesting that the

fricative /s/ preceding /a/ represents a negative skewness value, while /s/ preceding /i/ has a positive value. This finding showed that the construction position of the fricatives /s/ and /s'/ differed according to the vowel that followed. Compared with the vowels /a/ and /u/, the fricatives in Korean are palatalized before the /i/, and the spectrum spreads more toward the right-side and represents a predominant of energy in the lower frequencies. In addition, it is shown that the finding of this study is accounted for by the close correlation between the center of gravity and skewness. The mean center of gravity preceding /i/ was lower than that preceding /u/ or /a/ for both fricative sounds, so the skewness mean value preceding /i/ was higher than that preceding /u/ or /a/. That is, the higher the center of gravity is, the lower the skewness is. However, no other two-factor interactions were found. Figs. 3 and 4 represent the mean skewness of the fricatives /s/ and /s'/ according to dialect and gender.

Figs. 3 and 4 indicate that regardless of dialect and fricative category, male speakers produced positive skewness values, implying that they have a strong energy concentration in the lower frequencies resulting in a negative spectral tilt. The opposite result was seen for the female speakers. This result demonstrated that as the vocal tract is more retracted or backer when pronouncing a sound, the skewness value is closer to the positive. In addition, this finding supported the assertion by Nittrouer [21] that skewness is an acoustic cue for the gender-indexed marker.

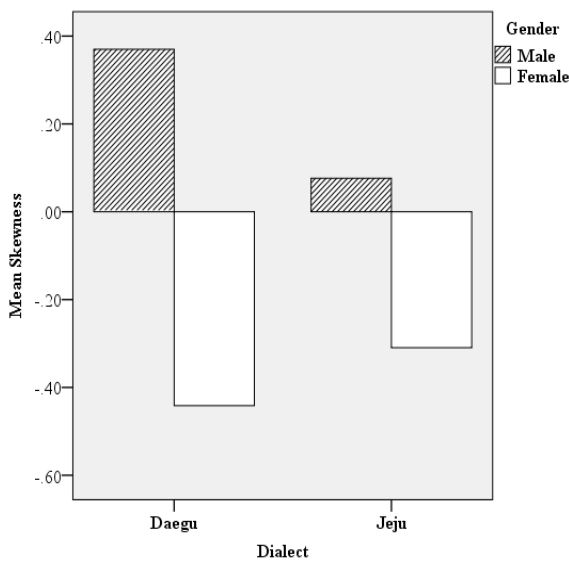


Fig. 3 Mean skewness of the /s/ as a function of dialect and gender

C. Rise Time

Table III represents the mean rise time values of the Korean fricatives /s/ and /s'/ in terms of dialect, fricative category, vowel context, and gender.

A three-way ANOVA (dialect × gender × vowel context) with the skewness as the dependent variable revealed that no main effect for either dialect or gender was found. This indicated that the rise time taken from the onset of the frication

noise to the maximum amplitude for the /s/ and /s'/ did not show any difference between dialect and gender. However, a main effect of vowel was found for the /s/ ([F(2,144)=31.164, p<0.001]), but not for the /s'/. Rise time for the /s/ was the longest for /i/ (66.05 ms), second longest for /u/ (55.67 ms) and the shortest for /a/ (33.47 ms), and Tukey HSD post hoc tests indicated that rise time was longer for the high vowel /i/ and /u/ than for the non-high vowel /a/. This can be accounted for by the relationship between vowel height and rise time, showing that they are proportional.

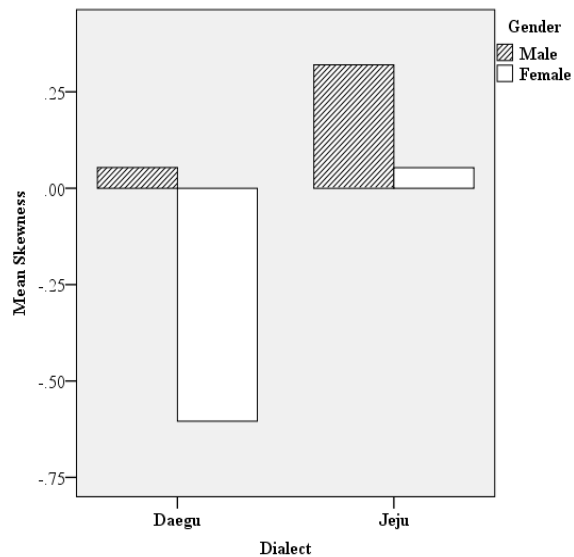


Fig. 4 Mean skewness of the /s'/ as a function of dialect and gender

TABLE III
MEAN RISE TIME OF THE KOREAN FRICATIVES /s/ AND /s'/, GROUPED AS A FUNCTION OF DIALECT, VOWEL CONTEXT, AND GENDER

| Consonant Phonation Type | Acoustic Parameter | Dialect | Vowel context | Gender | |
|--------------------------|--------------------|-----------|---------------|--------|--------|
| | | | | Male | Female |
| /s/ | Rise time | Daegu | /i/ | 72.46 | 62.94 |
| | | | /a/ | 38.99 | 32.90 |
| | | | /u/ | 60.61 | 56.26 |
| | | Average | 57.35 | 50.70 | |
| | | Jeju | /i/ | 67.43 | 61.39 |
| | | | /a/ | 31.36 | 30.64 |
| Average | 60.56 | 53.24 | | | |
| significance | p>0.05 | p<0.001** | p>0.05 | | |
| /s'/ | Rise time | Daegu | /i/ | 70.30 | 50.24 |
| | | | /a/ | 58.40 | 50.21 |
| | | | /u/ | 68.09 | 43.87 |
| | | Average | 65.60 | 48.11 | |
| | | Jeju | /i/ | 50.60 | 78.71 |
| | | | /a/ | 60.41 | 54.27 |
| Average | 68.37 | 69.24 | | | |
| significance | p>0.05 | p>0.05 | p>0.05 | | |

Note: p<0.05*, p<0.001**

As for the two factor interaction, a dialect × gender interaction was found for the /s'/ ([F(1,72)=11.916, p<0.001]), but not for /s/, indicating that for Daegu speakers, females (48.1 ms) have a shorter rise time than males (65.6 ms). This result demonstrated that when Daegu female speakers pronounced the

/s'/, they released the air more rapidly than males, causing the energy to rise abruptly. However, this tendency was not observed for the Jeju speakers. Figs. 5 and 6 represent the mean rise time of the fricatives according to dialect and gender for the /s/ and /s'/.

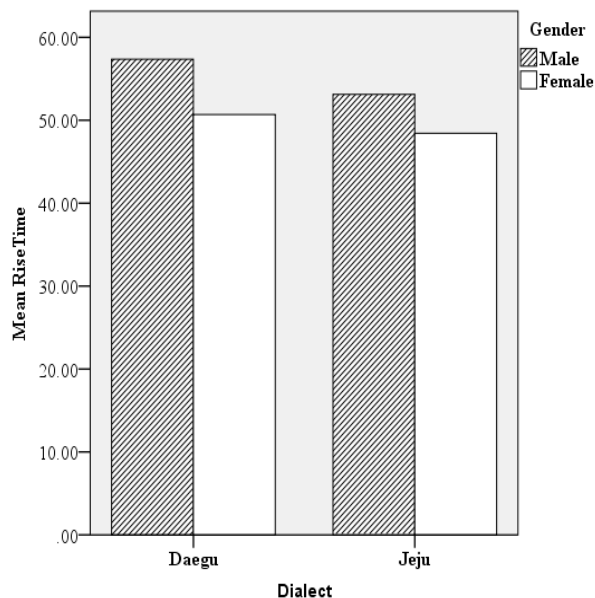


Fig. 5 Mean rise time of /s/ as a function of dialect and gender

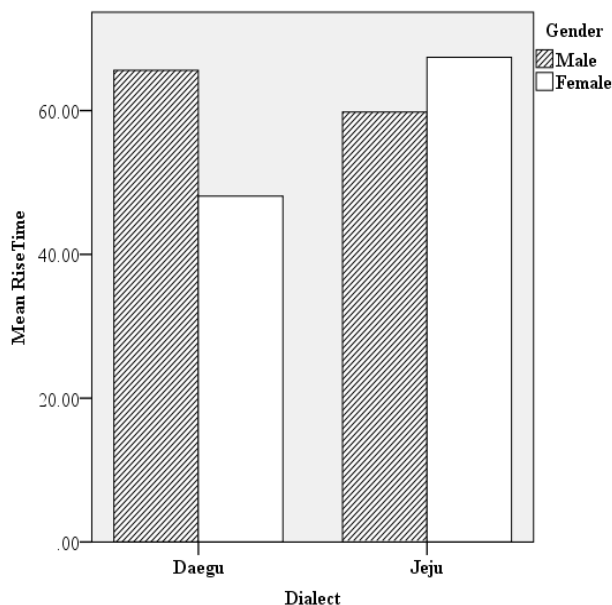


Fig. 6 Mean rise time of the /s'/ as a function of dialect and gender

D. Amplitude Rise Slope

Table IV represents the mean amplitude rise slope values of the Korean fricatives /s/ and /s'/ in terms of dialect, fricative category, vowel context, and gender.

A three-way ANOVA (dialect × gender × vowel context) with the amplitude rise slope revealed that like the rise time, no

main effect on both dialect and gender were found. It showed that the rate of increase in the amplitude of the acoustic wave energy through time for the /s/ and /s'/ did not show any significant difference for either dialect or gender. A main effect, however, was found for the vowel contexts for both the /s/ and /s'/.

For the /s/ ([F(2,72)=9.811, p<0.001]), the mean of the amplitude rise slope preceding /i/ was 0.03, /a/ was 0.09, and /u/ was 0.05. For the /s'/ ([F(2,72)=9.811, p<0.05]), For the /s'/ ([F(2,72)= 3.991, p<0.05]), the mean of the amplitude rise slope preceding /i/ was 0.04, /a/: 0.06, and /u/ was 0.04. Tukey HSD post hoc tests for the /s/ and /s'/ showed that the mean values for the /a/ was significantly higher than for the /i/ and /u/, indicating that the amplitude rise slope was steeper when followed by the low vowel /a/.

With respect to the interaction effect, a dialect × gender interaction ([F(1,72)=13.715, p<0.001]) revealed that for Daegu speakers, the /s/ produced by male speakers has a steeper rise slope compared to females. However, Jeju speakers did not show significant differences between the genders. That is, in the amplitude pattern, in case of Daegu dialect of speakers, males produced the /s/ with a rapid velocity of air emission than females, but in Jeju dialect of speakers, males and females produced it in a gradual manner for the velocity of air emission. Figs. 7 and 8 represent the mean rise time of the fricatives according to dialect and gender for the /s/ and /s'/.

TABLE IV
MEAN AMPLITUDE RISE SLOPE OF THE KOREAN FRICATIVES /s/ AND /s'/, GROUPED AS A FUNCTION OF DIALECT, VOWEL CONTEXT, AND GENDER

| Consonant Phonation Type | Acoustic Parameter | Dialect | Vowel context | Gender | |
|-----------------------------|-------------------------|---------|------------------|--------|--------|
| | | | | Male | Female |
| /s/ | Amplitude rise slope | Daegu | /i/ | 0.07 | 0.02 |
| | | | /a/ | 0.12 | 0.06 |
| | | | /u/ | 0.06 | 0.02 |
| | | Average | | 0.08 | 0.03 |
| | | Jeju | /i/ | 0.04 | 0.02 |
| | | | /a/ | 0.54 | 0.04 |
| /u/ | 0.05 | | 0.03 | | |
| Average | | 0.05 | 0.03 | | |
| significance | | p>0.05 | p<0.001* | p>0.05 | |
| /s'/ | Amplitude rise slope | Daegu | /i/ | 0.04 | 0.02 |
| | | | /a/ | 0.05 | 0.04 |
| | | | /u/ | 0.05 | 0.03 |
| | | Average | | 0.05 | 0.03 |
| | | Jeju | /i/ | 0.04 | 0.05 |
| | | | /a/ | 0.08 | 0.08 |
| /u/ | 0.04 | | 0.04 | | |
| Average | | 0.05 | 0.06 | | |
| significance | | p>0.05 | p<0.05* | p>0.05 | |

Note: p<0.05*, p<0.001**

IV. CONCLUSION

This preliminary acoustic study on speaker variability on the place and the manner of articulation for the two Korean fricatives /s/ and /s'/ demonstrated that the gender effect was found only for the place of articulation and not for the manner. In addition, no dialect effect was found for either the place or the manner of articulation, which contradicted the hypothesis by Kang et al. [22]. As for the gender difference in the acoustic cues for place of articulation, females exhibited significantly higher than males for the center of gravity and lower than males

for the skewness. This finding indicates that the two genders differed in where they pronounced the sounds, but not how they pronounced them, and that the center of gravity and the skewness played a role as gender-indexed markers. From solely the findings of this particular study, it is hard to prove that the frontedness of a sound produced by female speakers can be accounted for by either anatomical differences or socially-constructed cultural norms. In order to determine which hypothesis is more plausible to account for this phenomenon of frontedness, a study with participants of different age groups should be conducted.

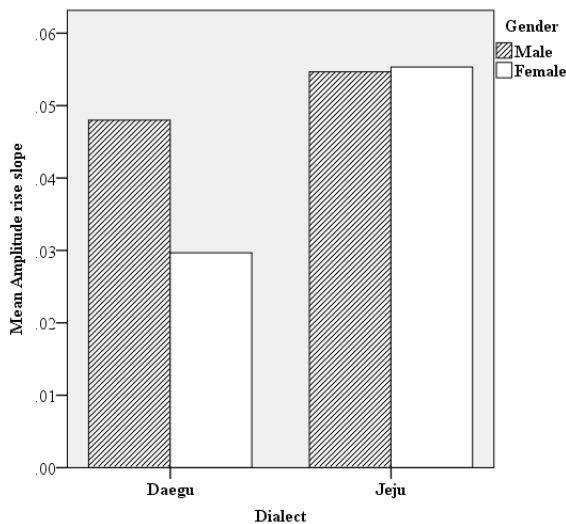


Fig. 7 Mean amplitude rise slope of the /s/ as a function of dialect and gender

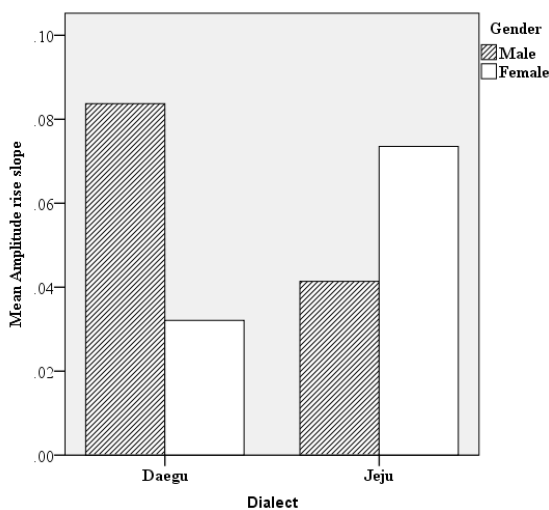


Fig. 8 Mean amplitude rise slope of the /s'/ as a function of dialect and gender

Although this study's results did not show a statistically significant difference in the manner of articulation with relation to speaker variations, it was noteworthy that there were differences between the two dialects of speakers and the two

genders for the acoustic parameters regarding the manner of articulation. Since the Daegu dialect is classified as having a tone-pitch accent in Korean, the effect of manner of articulation cues on tone should be studied in comparison to those effects in other tone languages.

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Kyung-Im Han is an assistant professor in College of Tabula Rasa, Keimyung University, South Korea. She received a Ph.D. in Linguistics at the University of Colorado, USA. She got a master's degree in Linguistics from the Catholic University of Daegu, in Korea. She has been teaching in Korea for more than 10 years. Her research interests include L1 and L2 pronunciation as well as diverse topics in acoustic phonetics and sociophonetics. (e-mail: kyungim@gw.kmu.ac.kr).