Gender Effects on Voice Cessation Time in Intervocalic Lax (Voiced) Obstruents

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ABSTRACT

This study examines whether gender influences voice cessation time (voicing duration) of lax (voiced) obstruents. Females more frequently show a posterior glottal opening throughout a vibratory cycle and have larger open quotients and less vocal fold contact than males. The gender differences imply that females can yield less voicing in their speech. In line with this, we hypothesized that the male voice is more voiced than the female voice in intervocalic lax (voiced) obstruents. This hypothesis was supported by the results of the present experiment, i.e., males exhibited significantly longer voicing and higher percentage of voicing relative to consonant duration than females during the intervocalic lax obstruents /p, t, k, c/ of Korean. Based on the results and the literature review, it is further hypothesized that the vocal folds are more likely adducted for males while abducted for females. The experimental data also indicated that males speak faster than females.

Keywords: Gender, Voice Cessation Time, Lax Obstruents, Open Quotients

1. Introduction

Men and women have many different characteristics in their speech organs and phonation. First, they are anatomically differentiated in speech organs. The average man has a larger larynx and longer vocal tract than the average woman does. The female vocal tract is about 87% of the male vocal tract in length (Fant, 1976), and this difference comes mostly from the pharynx (Goldstein, 1980). The membranous length of male vocal folds is 1.6 times longer than that of female ones, and the male thyroid cartilage is 1.2 times larger in the anterior-posterior dimension, and this ratio applies to the lateral and vertical dimensions as well (Kahane, 1978; Titze, 1989). The male vocal fold is about 20% thicker (Hollien, 1960). The female vocal

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folds have a bigger anterior angle and a wider posterior separation – "a more triangularly shaped vocal fold with a more linearly convergent glottis" (Titze, 1989, p. 1705). Second, males and females show significantly different phonatory and acoustic features, which seem to stem partly from the anatomical differences. Females more frequently show a posterior glottal opening throughout a vibratory cycle (Södersten & Lindestad, 1990) and have larger open quotients (Holmberg, Hillman & Perkell, 1988; Hanson & Chuang, 1999). Men have more vocal fold contact than women (Huggins & Schulte, 2002). The average fundamental frequency is 1.7 times higher in women than in men, though there are large variances between speakers in each gender (Peterson & Barney, 1952; Cooper & Sorenson, 1981). Females generally have larger relative amplitude of the first harmonic and have wider formant bandwidths than males (Childers & Wu, 1991; Hanson & Chuang, 1999). Females make greater acoustic excursions for shorter articulatory distances (Simpson, 2002). Men are more likely to produce creaky voice than women during the articulation of a vowel, while women are more likely to produce breathy voice than men (in British English (Henton & Bladon, 1985, 1987); in American English (Klatt & Klatt, 1990)). From the physiological point of view, more creaky voice is realised with a smaller open quotient (i.e., smaller proportion of a period during which the glottis is open), whereas more breathy voice would be characterised by a greater open quotient (i.e., greater proportion of a period during which the glottis is open) (Stevens, 1977; Klatt & Klatt, 1990). However, the male/female voice quality (breathy and creaky voice) appears to vary in different societies (Abberton, 2002). According to Thorne, Kramearae & Henley (1983), females are more dynamic in intonation contour than males, which may be learned behaviours. Gunzburger (1987) described that the male voice is characterised by large intensity, low pitch, small variance of intonation (pitch range) and fast speaking rate, as compared with the female voice. On the other hand, the female voice is more intelligible than the male voice, perhaps because females tend to speak more carefully and slowly (Marguilies 1979; Koopmans-van Beinum, 1980; Picheny, Durlach & Braida, 1985, 1986).

The existing literature reporting gender effects on voice quality mainly deals with vowels rather than consonants. Here, we extend our interest to consonants. The object of this research is to investigate whether gender affects voicing of intervocalic lax (voiced) obstruents or not, i.e., whether the degree of voicing significantly varies due to gender. With regard to this study, some of the above anatomical and phonatory differences between sexes are especially noted. They are (1) the female vocal folds have a bigger anterior angle and a wider posterior separation; (2) females more frequently show a posterior glottal opening throughout a vibratory cycle and have larger open quotients; (3) men have more vocal fold contact than women. These may imply that male vocal folds vibrate more easily than female ones, all others being equal. On the basis of the gender differences, therefore it was hypothesized that the male voice is more voiced in Korean intervocalic lax obstruents /p, t, k, c/ than the female voice.

As opposed to the traditional hypothesis – the phonologically voiceless lax stops /p, t, k/ and affricate /c/ are realised as voiced allophones in intervocalic position (Lee, 1989), frequently partial voicing or sometimes full devoicing does appear in intervocalic Korean lax obstruents (Yun, 2000). Considering the above differences in speech organs and phonation between men and women, it is worthwhile to examine possible gender effects on voicing of lax obstruents. In addition, it is suspected that gender may be one factor for the unstable and inconsistent occurrence of voicing in Korean lax obstruents. As far as I am aware, however, no study has been performed as to gender effects on voicing of Korean lax obstruents. On the other hand, English voiced stops hardly become voiced in word initial position frequently partially or fully devoiced in word final position, and frequently partially devoiced in medial position. Similar phenomena have been reported in voiced fricatives and affricates. As in Korean, however, it is very difficult to find studies that have examined gender effects on voicing of English voiced (lax) obstruents /b, d, g, dʒ, v, z, ð, ʒ/. But fortunately, we come across one study that observed a gender effect on voicing of English voiced stops. Smith (1975, p. S61) stated that "Male subjects exhibited both more frequent occurrence of voicing lead and greater prevoicing duration than females." Smith used ten male and ten female native English speakers to investigate voice onset time in initial voiced labial, dental and velar stops, and the speech materials were isolated CVC syllables. However, since then, gender effects on voicing of English voiced stops do not seem to have been noted and confirmed by other studies, and might have long been forgotten.

Apart from Smith (1975), two other investigations of English obstruents are found which were not targeted at gender effects on voicing but their results can be interpreted as implying gender differences. One is Kim's (1989) study as to the relationship between full voicing and the oral closure interval of a lax (voiced) intervocalic stop in British English. Two British English speakers (one male, one female) took part in the experiment as subjects. Interestingly, the results (Figures 1 and 2) show possible gender effects on voicing: the male speaker, in general, yielded considerably longer VCT (i.e., voicing) and apparently higher PCT (percentage of voicing relative to closure duration) than the female speaker, regardless of tempo and the place of articulation (bilabial /b/ and alveolar /d/). Considering the limited number of subjects in each gender (one of each sex), of course, the differences could be attributed simply to between-speaker variability rather than to gender effects. Nevertheless, it would not be wise to just ignore the possibility that the overall difference in VCT and PCT between the two speakers might stem in part from the difference in phonation between genders.

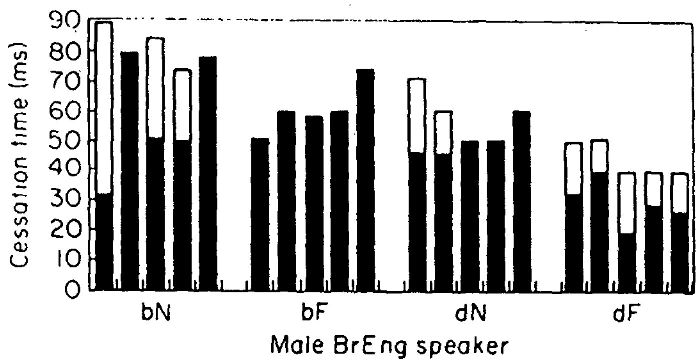

Figure 1. Voice cessation time of a male during the oral closure interval of BrEng intervocalic stops (N = normal speech, F = fast speech, b and d = stop consonants, whole bars: Duration of Oral Closure; black bars: VCT, n = 5) (from Kim, 1989, p. 241 with permission from Elsevier).

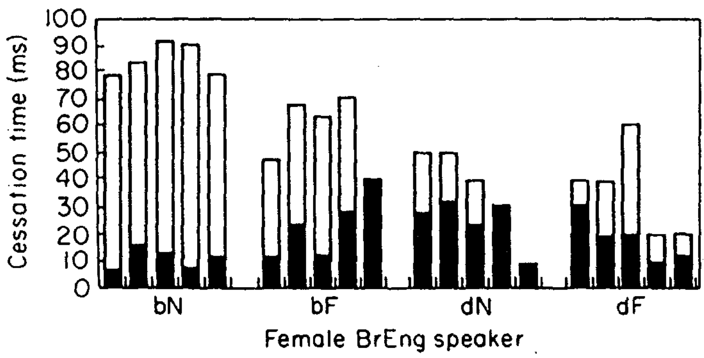

Figure 2. Voice cessation time of a female during the oral closure interval of BrEng intervocalic stops (N = normal speech, F = fast speech, b and d = stop consonants, whole bars: Duration of Oral Closure; black bars: VCT, n = 5) (from Kim, 1989, p. 242 with permission from Elsevier).

Smith (1997) may give us an additional threshold for the possible gender effects on voicing of English lax obstruents. She examined the devoicing of /z/ in a variety of phonological environments (syllable-/word-/sentence-final, syllable-/word-initial after a voiced stop or a vowel, etc.) using four native speakers (two males and two females) of American English. Simultaneous acoustic, airflow, and electroglottographic data were collected for the study. Figure 3 summarizes the results of each speaker across all tokens of /z/. With special reference to possible gender effects on voicing, it is of great interest that Speakers 1 and 3 were male while Speakers 2 and 4 were female. That is, Speaker 1 (male) voiced the most, Speaker 2 (female) devoiced the most, and the difference was noticeably great. Speakers 3 and 4 produced generally similar voicing patterns, but Speaker 4 (female) seems to be slightly less voiced than Speaker 3 (male). Her study, on the other hand, shows that there was considerable individual variation in different contexts. However, considering all speakers and contexts (i.e., Figure 3), some plausible gender effects appear to be perceived.

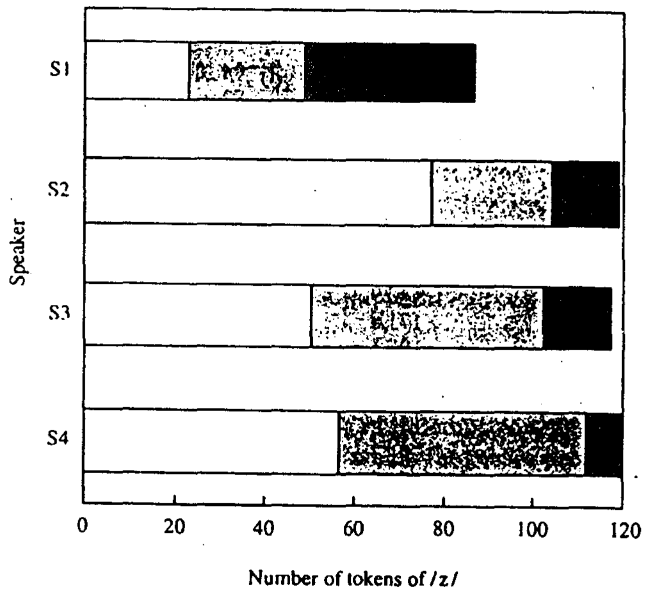

Figure 3. The total number of tokens of /z/ that each speaker produced as devoiced: blank bar, partially devoiced: gray bar, or fully voiced: black bar (from Smith, 1997, p. 481 with permission from Elsevier).

Originally the two studies, Kim (1989) and Smith (1997) did not intend to find out gender effects on voicing, and described the notable differences in voicing between speakers only in the aspect of inter-speaker variability. Their interpretations may be inevitable because of the small numbers of speakers. However, it should be pointed out that they might have missed good opportunities to report possible gender effects on voicing of English voiced obstruents.

Some plausible reasons are suggested why the gender effects on the voicing of voiced/lax consonants have stayed outside the interest of phoneticians. The first reason may be the fact that women and children have been less frequently chosen as subjects in acoustic studies for some reasons, e.g., their voices are less suitable in locating formant frequencies than the voices of men due to their high fundamental frequencies (Klatt & Klatt, 1990). Therefore, the acoustic or physiological data for women and children might have been less available. Secondly, in the early days of phonetics, few comparative studies regarding gender used a substantial number of male and female subjects (Henton & Bladon, 1987). More importantly, it should be pointed out that even the studies with a number of speakers from both sexes have focused on the production of vowels rather than consonants. Another reason can be limited by our perception. In practice, the phonologically voiced obstruents in English and the lax stops and affricate in Korean are likely to be intervocalically heard as voiced regardless of the presence or absence of phonetic voicing during the obstruents. In many cases, our impression of a given phenomenon could be the start of a study. For instance, creaky and breathy voices would be perceptually distinguished from normal voice, and especially creaky voice has been regarded as a sociophonetic marker of maleness. These perceptually observable phenomena would stimulate us to launch studies concerning the possible effects of gender on creaky or breathy voice. Whatever the reason is, the literature does not seem likely to provide sufficient references as to the difference in voicing during the lax obstruents of Korean and English due to gender. Nevertheless, should it be more frequent than chance that the male voice is more voiced in Korean lax intervocalic obstruents (stops and affricate) or in English voiced obstruents than the female voice, the gender effects on voicing of the lax (voiced) obstruents must be worthy of attention.

2. Method

2.1. Subjects

Twelve native speakers of Korean (six males and six females) aged between 20's and 30's took part in this experiment. All the speakers except one male had a

Seoul accent, which is the standard for Korean. The remaining speaker (M4) had a Kyungsang accent, which is used in the southeastern part of Korea. None of the speakers had hearing or speaking disorders.

2.2. Materials and procedure

The target word frame was /maCa/. The words embedding Korean lax stops /p, t, k/ and affricate /c/ were phonetically either real words (/mata/ "every", /maga/ "to block" or "a surname 'ma'", /maca/ "to be beaten") or a nonsense word (/mapa/), but all of them were natural to pronounce. Each of them was inserted into a sentence frame, "yeki /maCa/−do issta" (= Here is /maCa/, too.).

A reading list was prepared where the four carrier sentences embedding each of the four target words were written in six different orders. The twelve subjects delivered the sentences at their normal speech rates, yielding a total of 288 tokens (4 items (sentences) × 6 repetitions × 12 subjects). All participants were recorded using a recorder and a microphone in a sound treated recording room. The recording was digitised onto a Sun Sparcstation at a sampling rate of 16 kHz with 16 bit resolution and saved as files to be processed by the software package WAVES+ /ESPS. The targets of measurements include word duration, consonant duration (closure duration in stops, closure duration plus affrication in affricate) and voice cessation time (VCT) during the consonant duration. PCT (percentage of voicing relative to closure duration in stops /p, t, k/ or consonant duration in affricate /c/) was also calculated. Closure duration in stops was the interval from the end (the offset of the regular pulsing and formants) of the preceding vowel /a/ to the release of the stops. Duration of affricate /c/ was the interval from the end of the preceding vowel /a/ to the onset of the following vowel /a/.

3. Results and Discussion

The overall results across the four lax obstruents are presented in Figures 4 and 5. It is interesting that average male VCT and PCT values are markedly greater than female ones while the male voice shows a little shorter average consonant than the female voice. On the other hand, word duration is shorter in men than in women. In particular, shorter word duration can imply that males speak faster than females. The results were examined in more detail according to the consonants and speakers. For this purpose, we made Table 1 that illustrates individual and pooled PCT data together. On the whole, Table 1 shows noticeable inter- and intra-subject variability in the PCT distribution, irrespective of gender. Nonetheless, there is one general tendency: male speakers show more voicing than females - fully or mostly fully voiced tokens in stops /p, t, k/ or affricate /c/ are more frequently observed in male subjects.

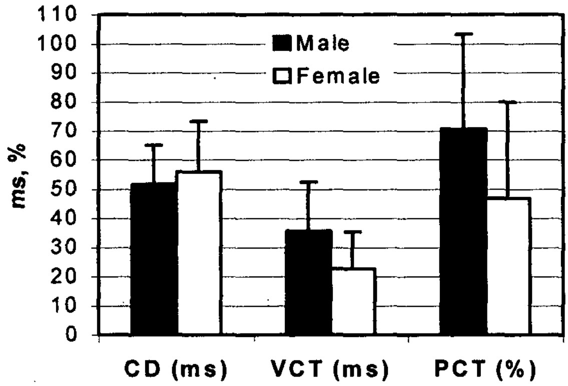

Figure 4. Mean CD (consonant duration: ms), VCT (voice cessation time: ms) and PCT (% of VCT relative to the closure duration of stops /p, t, k/, and the whole duration of affricate /c/), with standard error bars (six male and six female subjects, n = 144).

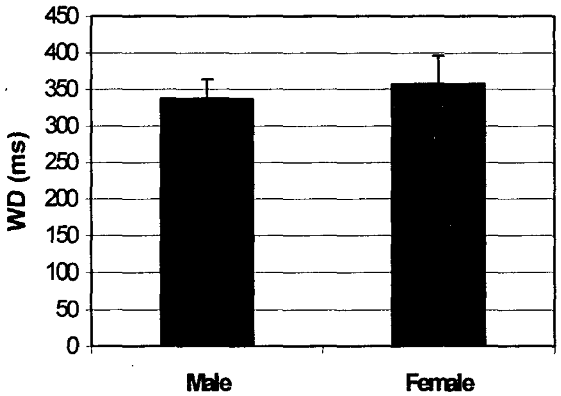

Figure 5. Mean WD (word duration: ms) across the words embedding /p, d, k, c/, with standard error bars (six male and six female subjects, n = 144).

One-way ANOVAs with Gender as a factor were conducted for VCT, PCT, CD (consonant duration) and WD (word duration) in each of the three lax stops and one affricate (see Table 2). In general, the factor Gender gave significant main effects on VCT and PCT except on PCT in /t/ ($p = 0.07$), which narrowly missed the significance level (p = 0.05), whereas it did not have main effects on CD save affricate /c/ (Male: 68.5 ms, Female: 77.5 ms). In other words, VCT and PCT significantly varied according to sex while the closure durations of stops were not different between sexes. In contrast, words embedding stops /b, d, g/ significantly varied in duration due to gender, except the word /maca/ with affricate /c/. Post-hoc Tukey's pairwise comparisons (p = 0.05) confirmed that the words with stops were shorter in males than in females. Though the durational difference was not significant in /maca/, males produced the word also shorter than females did (Male: 349.8 ms, Female: 361.7 ms). Hence, our data, in general, support that males speak faster than females, if shorter word duration means a faster speech rate.

Table 1. Individual and total PCT data in three lax stops /p, t, k/ and one affricate /c/ (in the order of the number of full voicing; partial voicing not lower than 50%; partial voicing lower than 50%; full devoicing). M: Male, F: Female, n = 36 in each gender

Subject	/p/	/t/	/k/	/c/
M1	0 / 4 / 2 / 0	0 / 2 / 4 / 0	5 / 1 / 0 / 0	0 / 0 / 6 / 0
M2	0 / 0 / 6 / 0	0 / 0 / 4 / 2	1 / 0 / 3 / 2	2 / 1 / 3 / 0
M3	6 / 0 / 0 / 0	6 / 0 / 0 / 0	6 / 0 / 0 / 0	2 / 1 / 3 / 0
M4	5 / 1 / 0 / 0	2 / 4 / 0 / 0	5 / 1 / 0 / 0	4 / 1 / 1 / 0
M5	5 / 1 / 0 / 0	3 / 3 / 0 / 0	6 / 0 / 0 / 0	0 / 1 / 5 / 0
M6	1 / 4 / 1 / 0	6 / 0 / 0 / 0	5 / 0 / 1 / 0	1 / 3 / 2 / 0
Sum of Males	17 / 10 / 9 / 0	17 / 9 / 8 / 2	28 / 2 / 4 / 2	9 / 7 / 20 / 0
F1	0 / 2 / 3 / 1	4 / 1 / 1 / 0	4 / 0 / 0 / 2	0 / 1 / 5 / 0
F2	1 / 1 / 4 / 0	0 / 4 / 2 / 0	2 / 0 / 3 / 1	0 / 0 / 6 / 0
F3	3 / 1 / 2 / 0	3 / 3 / 0 / 0	3 / 0 / 3 / 0	0 / 0 / 6 / 0
F4	0 / 0 / 5 / 1	0 / 2 / 4 / 0	2 / 0 / 3 / 1	0 / 0 / 5 / 1
F5	0 / 0 / 6 / 0	0 / 0 / 6 / 0	0 / 0 / 6 / 0	0 / 0 / 6 / 0
F6	4 / 0 / 2 / 0	1 / 3 / 2 / 0	5 / 0 / 1 / 0	0 / 0 / 6 / 0
Sum of Females	8 / 4 / 22 / 2	8 / 13 / 15 / 0	16 / 0 / 16 / 4	0 / 1 / 34 / 1

Table 2. Results of analyses of variance (F values): gender effects on VCT, PCT, CD (consonant duration) and WD (word duration) (subjects: 6 males and 6 females; n = 72)

Phoneme	VCT	PCT	CD	WD
/p/	8.33**	8.81**	3.02 ns	11.38**
/t/	4.75*	3.39 ns	1.78 ns	11.11**
/k/	17.3***	11.13**	0.08 ns	5.25*
/c/	29.33***	34.84***	11.67**	2.13 ns

ns: not significant, *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$

The result of the present experiment – male speakers show more voicing than females in the intervocalic lax stops /p, t, k/ and affricate /c/ – can be explained by the anatomical and phonatory differences between men and women, as we hypothesized earlier. In order to generate voicing during the hold phase of stops, the following three conditions should be met: (1) the appropriate subglottal air pressure; (2) the lightly adducted vocal folds with some muscular tension; (3) the expansion of the oral cavity (Netsell, 1969; Westbury, 1983; Ohala, 1983) or the increase of the pharynx volume (Perkell, 1969; Chomsky & Halle, 1968). Among them, our concern is focused on the second condition: "the lightly adducted vocal folds with some muscular tension". Unlike vowel production with sufficient subglottal air pressure and air stream, it is speculated that the voicing during the hold phase of a stop or affricate seems more likely to be constrained by the state of vocal folds. Namely, the vocal folds abducted at the back may not properly vibrate when the lung pressure is weak and the air stream is insufficient as during the hold phase of a stop If we interpret the fact that males have smaller open quotients and more vocal fold contact than females as meaning that male vocal folds are relatively more adducted and female vocal folds are relatively more abducted, the phenomenon – the male voice tended to be more voiced than the female voice during the lax stops and affricate – is explicable. This hypothesis (male vocal folds are relatively more adducted and female vocal folds are relatively more abducted) seems to shed light, especially, on the reason why the factor Gender had the most significant effects on the voicing (VCT or PCT) during the lax affricate /c/.

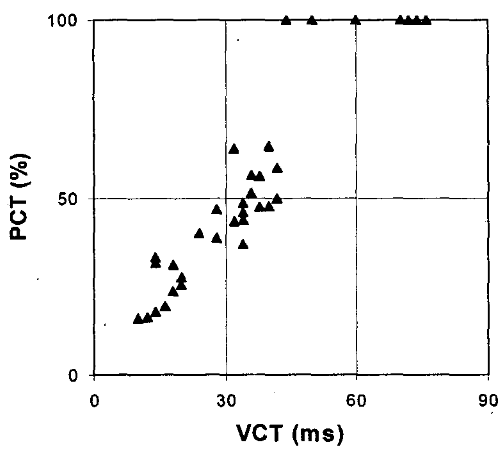

Figure 6. Distribution of Male Voicing in Intervocalic Lax Affricate /c/ (n = 36).

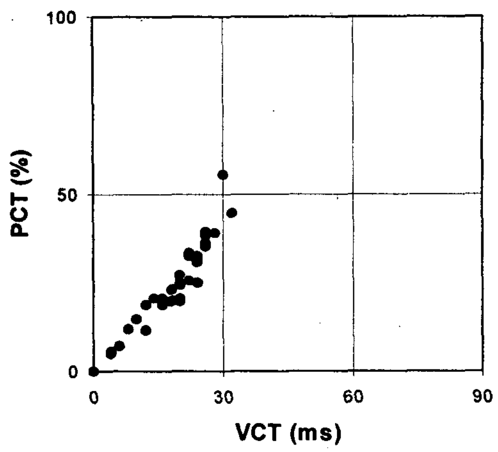

Figure 7. Distribution of Female Voicing in Intervocalic Lax Affricate /c/ (n = 36).

As seen in Table 1 and Figures 6, 7, almost all tokens of lax affricate /c/ with PCT not lower than 50% (i.e., 16 out of 17) were obtained from male subjects, which, in turn, indicates the vibration of vocal folds continues comparatively easily in male speakers, even after the release of the closure (i.e., during affrication). It is possible that during the period of affrication, the glottis opens relatively widely to allow more air to flow out and to generate noise between the supraglottal articulators approximated. However, the distance between male vocal folds which were relatively tightly adducted during the articulation of the preceding vowel /a/ could be still small enough to maintain vibration due to the increased air flow during the affrication of affricate /c/, whereas female vocal folds which were already relatively abducted during the articulation of the preceding vowel /a/ could be apart enough to cease vibration despite the abruptly increased air flow during the affrication of affricate /c/ On the other hand, it may be suggested that the significantly different VCT and PCT between men and women are attributed in part to shorter word or consonant durations in males than in females (cf. Silva, 1992). Yet, this differential should also be understood in the light of gender difference, i.e., males have a faster speaking rate than females (Marguilies, 1979; Koopmans-van Beinum, 1980; Picheny et al., 1985, 1986; Gunzburger, 1987). Moreover, some authors observed no significant and consistent relationship between speaking rate (consonant duration) and voicing in Korean obstruents (Kim, 1987; Yun, 2000) and in English obstruents (Kim, 1989; Smith, 1997).

4. Conclusion

Some anatomical and phonatory differences between genders (e.g., more open quotients in females than in males) suggest that the male voice may be more voiced than the female voice. This assumption was substantiated by our experimental data. That is, significant gender effects were observed on voicing in Korean intervocalic lax stops /p, t, k/ and affricate /c/, for which a hypothesis was set up: male vocal folds are more likely adducted, and female vocal folds are more likely abducted. Also, our data were generally consistent with the previous reports that males speak faster than females. On the other hand, the gender effects strengthen the view that voicing in Korean lax or English voiced obstruents is phonetic rather than phonological, i.e., gender appears to contribute to the unstable and inconsistent occurrence of voicing in Korean and English lax (voiced) obstruents. This issue remains open to further research and discussion.

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