Voicing in Intervocalic Lax Obstruents /p, t, k, c/ of Korean

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1. Introduction

Voicing is not a distinctive feature for Korean obstruents (three sets of stops: bilabial /p, p', ph/, alveolar /t, t', th/, velar /k, k', kh/; one set of affricates: /c, c', ch/; one set of fricatives: /s, s'/), as they are all phonologically voiceless. They are distinguished only by the feature tenseness and/or the feature aspiration. However, from a phonetic point of view, voicing especially in the intervocalic position has been noted in Korean lax stops and affricate. That is, a review of the literature reveals that the phonologically voiceless lax stops /p, t, k/ and affricate /c/ are realized as voiced allophones in the intervocalic position. Firstly some phoneticians view the realization of the full voicing is phonetic (Lisker & Abramson, 1964; Kim, 1965; Han & Weitzman, 1970, p. 112; Ladefoged, 1973, p. 81; Kagaya, 1974, p. 170; Lee, 1989, pp. 16-17). For instance, in a cross-linguistic study of voicing in stops, Lisker & Abramson (1964, pp. 413-414) states that "... the Korean middle category [lax stops] ... that takes on unbroken voicing [full voicing]". Kim (1965, p. 346) also says that "Word-medially, between voiced consonants or vowels, /p, t, k/ become voiced, ...", quoting the above Lisker & Abramson's (1964) statement. Though it is not clearly expressed, other studies also seem to interpret the realization of full voicing in Korean lax intervocalic stops from the phonetic point of view. But their claims were suggested without performing, if they did, reliable acoustic or articulatory experiments using a reasonably large number of subjects and proper equipment, or simply based on their own impression or knowledge. On the other hand, the full voicing hypothesis is interpreted phonologically (Kim-Renaud, 1974; Cho, 1990; Kang, 1992). They propose that the appearance of fully voiced allophones in the intervocalic position is a categorical change, while they do not show physical evidence regarding the hypothesis. They may point out that whether or not the lax stops and affricate are fully voiced is not important as far as native speakers of Korean tell them voiced, mentioning the case of English voiced obstruents. However, what native speakers of English identify (perceive) from a pair of words (e.g., rabid - rapid) may not be the existence of voicing (laryngeal buzz) in the voiced stop /b/, but the lexical

difference (Lisker, 1986). In addition, it should be noted that the phonetic base of phonological voiced/voiceless distinction of English stops is also rejected (Kim, 1987, 1989). And we need to remember that phonological rules should be supported by phonetic evidence. Otherwise, they must be isolated from the linguistic reality.

As opposed to the above, several studies (e.g. Kim, 1987; Kim, Hirose & Niimi, 1992; Silva, 1992; Jun, 1993, 1995; Han, 1994), are rejecting or doubting the above hypothesis. For instance, in a pilot experiment, Kim (1987) measured voice cessation time during the closure duration of lax stops in the isolated words /apa/, /ata/ and /aka/, using a laryngograph. The three speech items were pronounced five times at two different rates (normal and fast) by three native speakers of Korean. The result revealed only one token of full voicing out of 90 tokens. After confirming the findings through his main experiment using a sentence frame, he rejected the hypothesis that Korean lax stops /p, t, k/ are realised as voiced allophones in the intervocalic position. In a study to find out perceptual cues for Korean unaspirated tense and lax stops, Han (1994) used two words /opa/ (= an overcoat) and /op'a/ (= a girl's older brother) as speech materials for her perception tests. Out of six tokens of /opa/ obtained from a female native speaker of Korean, only one token was fully voiced, another one was partially voiced and the remainder were all fully devoiced. With the acoustic findings, Han (1994, p. 124) suggested that intervocalic voicing [in Korean stops] cannot be an important [perceptual] cue, indicating the assumption that the intervocalic lax stops become voiced allophonically is not consistently realized. Jun (1993, 1995) asserted that the voicing of Korean intervocalic lax stops should not be understood phonologically but phonetically. The rational for this study lies in the fact that despite the reports denying the full voicing hypothesis either phonetically or phonologically, the hypothesis is still taught in linguistic classes from the phonological or even phonetic point of view, depending on teachers. Hence we need to verify the hypothesis through an acoustic experiment using a considerable number of subjects. With regard to this controversial issue, the present research will add new data, which will, in turn, lead us nearer to the truth.

The literature shows another conflicting issue as to tempo effect on voicing in Korean intervocalic lax stops. That is, Jun (1990, 1993) claimed the faster the speech, the more likely a lax stop is to be voiced. Silva (1992) stated that the closure duration of a stop is negatively correlated with the percentage of voicing relative to closure duration (PCT). In contrast with the above researchers, Kim (1987) reported that fast speech rate reduced both closure duration and VCT (voice cessation time: duration of voicing during closure duration) in Korean lax stops, but PCT decreased, irrespective of subject [one male and one female] and the place of articulation [bilabial /p/ and alveolar /t/], since the magnitude of reduction of closure duration was smaller than that of VCT. Concerning English voiced stops as well, there are some views that full or nearly full voicing will more easily appear as the closure duration of a lax stop becomes shorter

(Gleason, 1955; Ohala, 1983). As in Korean lax stops, however, Kim (1987, 1989) opposed these views, showing that shorter closure duration (faster speech) did not automatically have full voicing (or a higher percentage of voicing). This claim is supported by Smith (1997) who reported no obvious and consistent correlation between speech rate and voicing during a voiced (lax) fricative /z/ in American English. Among the four subjects used, she stated, Speaker 2, who devoiced the most, spoke the most slowly, Speaker 1, who devoiced the least, spoke next most slowly, while Speakers 3 and 4 spoke the most rapidly. (p. 481). Relating to this conflicting issue, we will investigate the correlations between consonant duration and VCT and PCT in Korean lax obstruents /p, t, k, c/. The result should shed light on the effect of speech rate on voicing in Korean lax obstruents /p, t, k, c/ that is at present controversial.

2. Method

2.1. Subjects

Twelve native speakers of Korean (six males and six females) took part in all had a Seoul accent except one who had a Kyunsang accent (Speaker 6). No one had reportedly any hearing or speaking disorders.

2.2. Materials and procedure

The target word frame was /maCa/ where C was one of Korean three lax /p, t, k/ and affricate /c/. 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 nonsense word (/mapa/), but all of them were natural to pronounce. They were inserted into a sentence frame, yeki /maCa/-do issta (= Here is /maCa/, too.).

A reading list was prepared where the five sentences containing each of the five target words were written in six different order. The twelve subjects delivered it at their normal speech rate, yielding a total of 288 tokens (4 items (sentences) 6 repetitions 12 subjects). Recording was made using a high quality recorder and a microphone in the sound treated recording room of the Speech Research Laboratory at Reading University. The recording was digitized 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. From the files, waveforms and spectrograms were generated. The targets of measurements include consonant duration (closure duration in stops), noise (in affricate), and voicing duration (voice cessation time: VCT) during the closure duration of stops,

and VCT during the whole consonant duration (closure duration plus affrication) of affricate.

3. Results and Discussion

3.1. Full voicing hypothesis in Korean intervocalic lax stops /p, t, k/ and africate /c/

3.1.1. Results and discussion across all subjects

Consonant durations (CD), VCT (voice cessation time: voicing duration during the closure duration of stops /p, t, k/ and voicing duration during the whole duration of affricate /c/) and PCT (VCT as percentage of consonant duration) obtained from the spectrograms and waveforms of each token are presented in Table 1. These data should provide answers for the two questions raised earlier: Are Korean intervocalic lax stops /p, t, k/ and affricate /c/ fully voiced?

Table 1. Mean CD (consonant duration), VCT (voice cessation time: ms) and PCT (percentage of VCT relative to the closure duration of stops /p, t, k/, and the whole duration of affricate /c/) across twelve subjects. (SD: standard deviation), MIN (minimum %), MAX (maximum %), Number of Full Voicing and Number of Full Devoicing (n = 72)

Type	p	t	k	c
CD	50.06 (9.63)	46.33 (9.94)	43.97 (11.10)	72.86 (12.36)
VCT	30.53 (16.55)	29.39 (13.54)	29.75 (17.16)	27.44 (17.30)
PCT	60.63 (33.54)	65.32 (30.88)	69.83 (39.46)	39.56 (27.10)
MIN	0	0	0	0
MAX	100	100	100	100
N. FV	25	25	44	9
N. FD	2	2	6	1

As seen in Table 1, the three lax stops /p, t, k/ have substantial intervals of devoicing during their closure duration respectively (i.e. /p/: 39.37%; /t/: 34.68%; /k/: 30.17%). Furthermore, the strikingly large standard deviations of PCT (/p/: 33.54; /t/: 30.88; /k/: 39.46) clearly show the instability of voicing in lax stops. The lax affricate /c/ disclosed a rather longer mean interval of devoicing (60.44 %) during the consonant duration than those of lax stops, and also a large standard deviation (27.1).

Apart from the devoicing intervals and standard deviations, the PCT values of every lax stop /p, t, k/ and affricate /c/ range from 0% to 100%. Thus, the widely dispersed range of PCT is not likely to be in favour of the existing claim: Korean lax stops and

affricate show full voicing in the intervocalic position.

One may point out that Table 1 shows large numbers of full voicing tokens in the three lax stops respectively (out of 72 tokens, /p/: 25; /t/: 25; /k/: 44). On the other hand, a relatively small number of full devoicing tokens was observed in each lax stop (out of 72 tokens, /p/: 2; /t/: 2; /k/: 6). Thus, based on these, one may support the hypothesis of full voicing in Korean intervocalic lax stops. Yet, it should be taken into account that even tense consonants frequently show partial voicing and the small number of full devoicing tokens is not powerful enough to be evidence of the full voicing hypothesis. Taken together with all the data above, therefore, it seems reasonable to reject the hypothesis (i.e. Korean intervocalic stops and affricate are fully voiced). That is, the substantial devoicing, large amount of variability of PCT (SD) and extremely wide range of PCT occurrences (0% - 100%) look strong enough to weaken the large number of full voicing tokens as evidence of general full voicing in Korean intervocalic lax stops.

In particular, when it comes to the lax affricate /c/, no factor is found to support the full voicing hypothesis during the consonant, including the number of full voicing tokens. Only 9 full voicing tokens out of 72 are obviously insufficient to be adopted as phonetic evidence to support the general occurrence of full voicing during the consonant, and not strong enough to compete with the noticeably long mean interval of devoicing (60.44%), markedly large standard deviation of PCT (27.1) and also extremely wide range of PCT occurrences (0% - 100%). Accordingly, the claim found in the literature (i.e. that the phonologically voiceless lax affricate /c/ is pronounced fully voiced in the intervocalic position) should be rejected as far as the data from this experiment are concerned.

In an attempt to secure additional evidence to judge whether or not the lax stops and affricate in this experiment were realised as fully voiced allophones in the intervocalic position, the 95.0 % confidence interval was investigated for their respective PCT values, by using one-sample t-test (binomial proportion). Out of 72 tokens, fully voiced tokens, and partially voiced tokens whose PCT was not less than 50% were counted as 1, whereas partially voiced tokens with lower PCT than 50% and fully devoiced ones as 0. The statistical results are presented in Table 2.

Table 2. 95.0% confidence intervals of PCT from the three lax consonants /p, t, k/ and one affricate /c/ (full voicing, and partial voicing whose PCT is not lower than 50%: 1; partial voicing with lower PCT than 50% and full devoicing: 0). (n = 72)

Type	Mean	95.0% C.I.
bilabial lax stop /p/	0.5417	(0.4237, 0.6596)
alveolar lax stop /t/	0.6528	(0.5401, 0.7655)
velar lax stop /k/	0.6389	(0.5252, 0.7526)
lax affricate /c/	0.2361	(0.1356, 0.3366)

The results show that although even the partially voiced tokens, whose PCT was not less than 50%, were counted as full voicing, all the 95.0% confidence intervals stay substantially lower than 1 (full voicing), which would be further negative evidence to the full voicing hypothesis in either intervocalic lax stops /p, t, k/ or affricate /c/.

3.1.2. Individual results and discussion

Now, we need to inspect the results subject by subject, apart from the pooled data. Table 3 illustrates the individual PCT data. That is, out of six tokens in each lax stop and affricate, the number of full voicing tokens was put in the first column, the number of partial voicing whose PCT was not lower than 50% in the second column, the number of partial voicing with lower PCT than 50% in the third column and the number of full devoicing in the last column.

Table 3. Individual 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)

Subject	/p/	/t/	/k/	/c/
S1	0 / 4 / 2 / 0	0 / 2 / 4 / 0	5 / 1 / 0 / 0	0 / 0 / 6 / 0
S2	0 / 0 / 6 / 0	0 / 0 / 4 / 2	1 / 0 / 3 / 2	2 / 1 / 3 / 0
S3	6 / 0 / 0 / 0	6 / 0 / 0 / 0	6 / 0 / 0 / 0	2 / 1 / 3 / 0
S4	5 / 1 / 0 / 0	2 / 4 / 0 / 0	5 / 1 / 0 / 0	4 / 1 / 1 / 0
S5	5 / 1 / 0 / 0	3 / 3 / 0 / 0	6 / 0 / 0 / 0	0 / 1 / 5 / 0
S6	1 / 4 / 1 / 0	6 / 0 / 0 / 0	5 / 0 / 1 / 0	1 / 3 / 2 / 0
S7	0 / 2 / 3 / 1	4 / 1 / 1 / 0	4 / 0 / 0 / 2	0 / 1 / 5 / 0
S8	1 / 1 / 4 / 0	0 / 4 / 2 / 0	2 / 0 / 3 / 1	0 / 0 / 6 / 0
S9	3 / 1 / 2 / 0	3 / 3 / 0 / 0	3 / 0 / 3 / 0	0 / 0 / 6 / 0
S10	0 / 0 / 5 / 1	0 / 2 / 4 / 0	2 / 0 / 3 / 1	0 / 0 / 5 / 1
S11	0 / 0 / 6 / 0	0 / 0 / 6 / 0	0 / 0 / 6 / 0	0 / 0 / 6 / 0
S12	4 / 0 / 2 / 0	1 / 3 / 2 / 0	5 / 0 / 1 / 0	0 / 0 / 6 / 0
Total: 72	25 / 14 / 31 / 2	25 / 22 / 23 / 2	44 / 2 / 20 / 6	9 / 8 / 54 / 1

On the whole, Table 3 shows marked inter-subject variability and intra-subject variability in the PCT distribution. Firstly, four male subjects S4, S6, S11 and S12 manifested nearly full voicing during their lax stop closure durations. This might be in favour of the full voicing hypothesis in intervocalic lax stops /p, t, k/. In contrast, the results of another four subjects S2, S5, S8 and S9 are unlikely to support the hypothesis. The results of the remaining four subjects S1, S3, S7 and S10 appear to be in a neutral position. On the other hand, considerable intra-subject variability is observed from many

subjects (e.g., full voicing and full devoicing coexist in the same subject (S2, S3, S5, S8) and phoneme /k/). In the lax affricate /c/, except for subject S6 who seems to show nearly full voicing, the individual PCT data reject the claim that the phonologically voiceless lax affricate /c/ becomes a fully voiced allophone in the intervocalic position.

The above individual results lead us to a conclusion that the so-called full voicing in lax stops and affricate may occur or may not depending on the speaker, all other things being equal (e.g., the text where the lax obstruents are located), and the occurrence of full voicing is not liable to be consistent between speakers, between lax phonemes (three lax stops and one lax affricate), and even within speakers. Hence, it is proposed that the current hypothesis in the literature should be modified. First, as is already indicated by other studies, the full voicing hypothesis is rejected from the phonetic point of view. Second, from the phonological point of view as well, the full voicing hypothesis loses its base that should be supported by phonetic evidence. Here, one may argue that full voicing is not necessarily needed to establish related phonological rules. But the results of this experiment (i.e. the noticeably long mean interval of devoicing, markedly large standard deviation of PCT, extremely wide range of PCT occurrences (0% - 100%) and great inter-/intra-subject variability in the PCT distribution) are not in favour of even the phonological assumption (voiced allophones). Moreover, provided that listeners distinguish voiced/lax consonants from their cognates under the condition no voicing (full devoicing) is given during the voiced/lax English or Korean consonants, how can we say that the distinctive feature is voicing: voicing in the consonants plays a crucial role in perception? Should native speakers of English or Korean differentiate a fully devoiced English voiced or Korean lax intervocalic stop from its cognate (e.g., English: rabid - rapid; Korean apa - ap'a or apha), the feature voicing will be merely a redundant feature. In that case, the distinctive feature in the pair words should be found elsewhere (e.g., duration or tensity).

3.2. Correlations between consonant duration (tempo) and VCT, and PCT in Korean intervocalic lax stops /p, t, k/, affricate /c/

3.2.1. Results and discussion across all subjects

The correlations were examined between consonant duration and VCT, and between consonant duration and PCT in intervocalic lax stops /p, t, k/ and affricate /c/. This experiment did not directly investigate the effect of tempo on voicing in intervocalic lax consonants (i.e. only a normal rate of speech was applied). However, the correlations between consonant duration and PCT can be used as an indicator of tempo effect on voicing and at least they will verify Silva's (1992) claim. Table 4 shows the results.

Table 4. Correlation coefficients between consonant durations (tempo) and VCT, and PCT in intervocalic lax stops /p, t, k/, affricate /c/ and fricative /s/ (C: consonant duration, ns: not significant: 0.31< r < 0.31; n = 72)

Correlation	/p/	/t/	/k/	/c/
C : VCT	-0.004 ns	+0.116 ns	+0.127 ns	-0.340 *
C : PCT	-0.325 *	-0.289 ns	-0.221 ns	-0.498 *

*:p < 0.05

First, the correlations of consonant duration and VCT are not significant except the case of the affricate /c/. Moreover, the correlations were not consistent across consonants (negative in /p/ and /c/, while positive in /t/ and /k/). Second, consonant duration and PCT, in general, do not appear to have strong correlations, either, even if significant correlation coefficients were obtained from /c/ and /p/. Yet, it appears to be notable that the correlations are all negative in lax stops and affricate, disregarding significance. That is, for the pooled data, there seems to be, though weak, a tendency: the shorter the consonant duration (the faster), the greater the PCT.

3.2.2. Individual results and discussion

For each speaker, correlation coefficients between consonant duration and PCT were examined in lax stops /p, t, k/ and affricate /c/, and the results are presented in Table 5.

Table 5. Individual correlation coefficients between consonant durations (tempo) and PCT in Korean intervocalic lax stops /p, t, k/ and affricate /c/. (--- denotes full voicing in all 6 tokens where no correlation coefficients are available; ns: not significant: 0.73 < r < +0.73; n = 6).

Subjects	/p/	/t/	/k/	/c/
S1	+0.003 ns	-0.292 ns	+0.777 *	-0.362 ns
S2	-0.593 ns	+0.272 ns	-0.339 ns	-0.669 ns
S3	-0.258 ns	+0.363 ns	+0.239 ns	-0.625 ns
S4	---	---	---	-0.867 *
S5	-0.753 *	+0.536 ns	-0.552 ns	+0.891 *
S6	-0.121 ns	-0.035 ns	-0.445 ns	-0.702 ns
S7	-0.863 *	-0.908 *	-0.751 *	-0.740 *
S8	-0.625 ns	-0.136 ns	-0.759 *	+0.610 ns
S9	-0.215 ns	-0.724 ns	+0.769 *	-0.382 ns
S10	-0.283 ns	-0.110 ns	+0.332 ns	-0.457 ns
S11	+0.530 ns	+0.146 ns	---	-0.199 ns
S12	-0.608 ns	---	+0.054 ns	-0.340 ns

*: p < 0.05

As seen in Table 5, two subjects (S4 and S7) only show consistent and significant negative correlation coefficients between consonant duration and PCT in intervocalic lax

stops /p, t, k/ and affricate /c/. For the two subjects, therefore, it can be said that the shorter the consonant duration (the faster the speaking rate), the greater the PCT. Except for the two subjects, however, remarkable variability is observed between speakers and within speakers irrespective of the place and manner of articulation. Thus, despite the presence of some overall weak tendency (see Table 4) and the two subjects who show consistent and significant negative correlation coefficients, it seems to be difficult to generalize that consonant duration is negatively correlated with PCT (i.e. the faster the speech, the more likely lax stops and affricate are to be voiced).

Considering these results, we would be able to explain both of the opposite claims introduced earlier. That is, it can be said that significant negative correlations between the duration of a lax consonant and PCT could occur according to speaker and the place and manner of articulation, but at the same time the correlations could be frequently non-significant or even significantly positive according to speaker and the place and manner of articulation. The former will support Jun (1990, 1993), Silva (1992), Gleason (1955) and Ohala (1983), whereas the latter will be in support of Kim (1987, 1989) and Smith (1997). All in all, however, it seems to be reasonable to suggest that faster speech does not necessarily cause a higher PCT in Korean lax stops and affricate or in English lax (voiced) obstruents. The idea that in a faster rate of speech (or shorter duration), a higher percentage of voicing will appear during Korean lax and English voiced obstruents is likely to be a language myth. There might be some factors other than tempo (closure duration) which cause longer VCT or higher PCT.

4. Summary and Conclusion

This study was aimed at examining two controversial hypotheses: (1) the phonologically voiceless Korean lax stops /p, t, k/ and affricate /c/ are realised as voiced allophones in the intervocalic position (2) the faster the speech, the more likely a lax stop is to be voiced (i.e. the closure duration of a lax stop is negatively correlated with the percentage of voicing relative to closure duration (PCT)). First, the results of the experiment revealed that full voicing did not always appear in Korean intervocalic lax stops /p, t, k/ and affricate /c/, while substantial devoicing and marked standard deviations of PCT were observed. There was great variability between/within speakers and between phonemes (i.e. the place and manner of articulation). Accordingly the first hypothesis is rejected: the conventional full voicing hypothesis should be modified. Second, shorter consonant duration did not necessarily induce higher PCT. That is, the correlations between consonant duration and VCT or PCT, in general, were not significantly high for the pooled data (across all subjects). In addition, the correlations individual speakers yielded between consonant duration and PCT had a great variation ranging from significantly negative correlations to significantly positive correlations.

There was great variability between and within speakers, and between phonemes (i.e. the place and manner of articulation). Similar observations concerning tempo effect on voicing of lax obstruents have been reported in English voiced stops (Kim, 1989; Smith, 1997). In consequence, the second hypothesis - the shorter the lax consonant, the higher the percentage of voicing - is also rejected.

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