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An Acoustic Analysis of the Aspiration Merger in Korean

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ABSTRACT

In Korean, 'Aspiration Merger' is the result of the heteromorphemic sequence of lenis stop and /h/ becoming a single aspirated stop word-medially. However, the contrast between lenis stop-plus-/h/ and an underlying aspirated stop is maintained when they span Phonological Phrase boundaries. By varying the position in the prosodic domain such as APP (Across Phonological Phrase) and PPM (Phonological Phrase Medial) positions, the phonetic properties of the two categories are compared. In the results from noise duration and change of intensity, lenis stop-plus-/h/ show a large difference between the APP and PPM positions. The results from a noise duration comparison show that the two categories are completely neutralized into aspirated stop in the PPM position and the complete neutralization is sensitive to prosodic phrasing.

Keywords: aspiration merger, neutralization, timing of gestures

1. Introduction

This paper presents data bearing on the question of what happens at the phonetic level during a sound change of the type which is referred to as 'Aspiration Merger' (Kim-Renaud, 1986; Lisker and Abramson, 1964) in Korean. In Korean, the heteromorphemic sequences of lenis stop and /h/ become an aspirated stop in the word-medial position. For example, in (1), when the word beginning with [h] such as [hak] ('study'), [haŋ] ('a clause') and [ham] ('ship') are preceded by the words [pəp] ('law'), [ʧhət] ('the first') and [ʧək] ('an enemy'), a single aspirated stop appears in intervocalic position instead of the sequence of [..ph..], [..th..] or [..kh..].

(1) derived aspirated stop from lenis stop-plus-/h/
   a. [pəp] 'law'   [hak] 'learning, study'
      → [pəp^{h}ak] 'jurisprudence'
   b. [ʧ^{h}ət] 'the first'   [haŋ] 'a clause'
      → [ʧ^{h}ət^{h}aŋ] 'the first clause'
   c. [ʧək] 'en enemy'   [ham] 'ship'
      → [ʧəkham] 'an enemy warship'

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On the distribution of the aspirated stop and lenis stop-plus-/h/, aspirated stops appear in word-initial position such as [p^{h}a] ('green onion') and [t^{h}al] ('mask'). On the contrary, lenis stop-plus-/h/ cannot occur word-initially since Korean does not allow complex onset generally. Both aspirated stop and lenis stop-plus-/h/ fail to surface in coda position because Korean allows only unreleased consonants such as [p, t, k, m, n, ŋ, l] in coda position. In word-medial position, aspirated stops appear in the word such as [ki.p^{h}o] 'air bubble' and [hwaŋ.t^{h}o] 'mud', while the lenis stop and /h/ cannot surface in the sequence of lenis stop-plus-/h/ in the word such as *[pəp.hak] or *[pə.phak] ('jurisprudence'). That is, aspirated stops and lenis stop-plus-/h/ lose the contrast and surface as an aspirated stop in word-medial position.

However, beyond the Word boundary, both aspirated stops and lenis stop-plus-/h/ can appear. Across the Phonological Phrases (PP), aspirated stop and lenis stop-plus-/h/ show the contrast. The sequence of lenis stop-plus-/h/ is realized as in (2a) and the aspirated stops also occur as in (2b). The target segment is underlined below.

(2) aspirated stops and lenis stop-plus-/h/ beyond the Word boundary
   a. [IP [PP kɨ ʧikap] [PP Hant^{h}e-nɨn sirə-he]]
      That purse Hante-Top dislike-do

‘Hante dislikes the purse.’

b. [IP [PP Sonjə-ka] [PP p^hado-lɨl ʧoa-he]
girl-Nom waves-ACC like-do
‘The girl likes waves.’

Since the study of the Aspiration Merger has been limited within the Word boundary (Kim, 1970; Iverson and Kim-Renaud, 1998), it has not been studied whether the Aspiration Merger is sensitive to the phonological phrasing so far. In addition, there were few studies examining the phonetic properties of the Aspiration Merger. The current study therefore attempted to examine the acoustic properties of lenis stop-plus-/h/ with and without the Aspiration Merger. In order to compare lenis stop-plus-/h/ with and without the Aspiration Merger, it is necessary to vary the prosodic domain beyond the Word domain since lenis stop-plus-/h/ cannot occur in the Word domain in Korean. So, a domain which is larger than the Phonological Word is adopted in this study.

Before presenting the previous analyses of the Aspiration Merger, I briefly introduce Korean stop consonants and their acoustic properties, and phonological phrasing in Korean in section 1.1 and 1.2.

1.1 Korean Stops

Korean has a three-way phonation contrast among voiceless lenis ([p, t, k]), aspirated ([p^h, t^h, k^h]) and fortis stops ([p’, t’, k’]) and each of these occurs at three places of articulation: bilabial, alveolar and velar. They use the pulmonic egressive airstream.

The phonetic correlates of this three-way contrast have been examined by many researchers. I briefly present the results of the previous studies focusing on the distinction between the aspirated stops and lenis ones. In an acoustic study, Lisker & Abramson (1964) showed that Korean aspirated stops have the longest VOT, lenis consonants an intermediate VOT, and tense ones almost zero VOT. However, several researchers found that VOT of lenis and aspirated stops can overlap (Kim, 1965; Han and Weitzman, 1970; Cho et al., 2002). Han and Weitzman (1970) claimed that the acoustic intensity build-up in a vocalic segment following the three-way phonation contrast is highest after the fortis consonants, intermediate after the aspirated and lowest after the lenis ones, contributing to the laryngeal distinction. They suggested that the onset value of F0 after aspirated consonants is higher than that of lenis ones. This result showed that F0 contrasts serve as a supplementary cue to distinguish lenis stops from aspirated ones.

It was also noted that lenis stops have a high degree of aspiration, at least for Seoul speakers and there is a change in progress concerning the contrast between lenis and aspirated stops. VOT differences between lenis and aspirated stops have decreased, in some cases to the point of complete overlap. In the perception study, it was confirmed that speakers are relying more heavily on the pitch/tone differences between lenis and aspirated stops than the VOT differences (Silva, 2006; Wright, 2007).

In Kagaya’s (1974) fiberscopic study of the three-way phonation contrast in word-initial stops and affricates, glottal opening varies from small to large in the order lenis < aspirated. In another fiberscopic study, Jun, Beckman and Lee (1998) found similar results in terms of the timing and size of the glottal opening for the Korean three-way laryngeal contrast in initial position. In the stroboscopic-cine MRI experiments, Kim et al. (2005) found that concomitant tongue and larynx movements and glottal opening varied from low (short) to high (long) in the order lenis < aspirated. They showed that the glottis opens much wider for the aspirated consonants than for the tense and lenis ones word-medially and word-initially.

1.2 Prosodic Hierarchy in Korean

Speech utterances are hierarchically organized, with higher units being decomposed into lower constituents (Nespor and Vogel, 1986; Selkirk, 1986). The sample structure of the hierarchical organization of the prosodic domains is given in Fig. 1.

The figure in (1) illustrates that Syllables are grouped into Words; Words are grouped into Phonological Phrases (or Accentual Phrases); Phonological Phrases are grouped into Intonational Phrases. In Seoul Korean, the intermediate phrase between Words and Intonational Phrases is usually marked by LHLH or HHLH[2] tonal pattern (Jun, 1993, 1998).

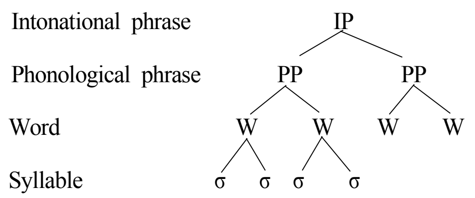


Figure 1. Prosodic structure of Korean

2) The PPs start with H when the target segments are fortis, aspirated stops, or fricatives as noted in Jun (1993, 2000).

The organization of this paper is as follows. Previous analyses about the Aspiration Merger are shown in section 2. In Section 3, the research methods and the hypothesis of this study are provided. In section 4, the results of the experiment are discussed. Section 5 concludes the paper.

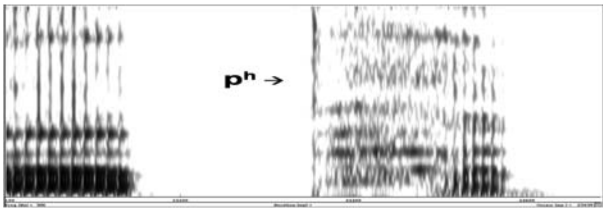
2. Previous Analyses

To explain the Aspiration Merger, Kim (1970) took the position of the coalescence analysis which merges the two segments, /h/-plus-lenis stop or lenis stop-plus-/h/, into a single aspirated stop directly. Kim (1970) pointed out that aspiration may be interpreted as a laryngeal gesture inherent in the articulation of the stop itself. So, aspiration was represented by a feature rather than a segment and the observed effect of /h/ on adjacent lenis stops would appear to be the result of coalescence of lenis stop-plus-/h/ into a single aspirated stop.

Another analysis put forth by Iverson and Kim-Renaud (1998) is assimilation. Under this account, /h/[3]-plus-lenis stop and lenis stop-plus-/h/ resulted in the bisegmental representation. They contended that aspiration spreads material specified in the left segment into positions underspecified in the right segment retaining the bisegmental structure of the input representation: the stop's oral cavity configuration spreads into the unspecified root node of the following glottal approximant. That is, the stop acquires the aspiration or [spread glottis] property of /h/ in the lenis stop-plus-/h/ sequence.

From the traditional phonological data, the aspirated stops were distinguished from lenis stop-plus-/h/. However, there is some evidence showing the physical similarity between lenis stop-plus-/h/ and aspirated stop. For example, articulatorily, they both consist of an oral closure followed by an oral and a glottal opening. Acoustically, they are composed of a gap in intensity followed by an interval of aspiration noise as in Fig. 2. Therefore, it seems that the difference between the two categories lies in the timing of the gestures[4]. In results of the Swedish and Icelandic studies, Löfqvist and Yoshioka (1980) claimed that combinations of voiceless stop and voiceless fricative or voiceless fricative and voiceless unaspirated stop generally contain only one glottal articulatory gesture, with peak glottal opening occurring during the fricative. Likewise, it is expected that in lenis stop-plus-/h/, the glottal spreading gesture lies in the /h/ but in the aspirated stop, the gesture peaks around the release. We can therefore suspect that the same physical events are presented with two transcriptions in the phonology. In order to find out the physical similarity between the two categories, it is necessary to do the phonetic experiment.

(a) Spectrogram of [p^h] taken from a word '*p^{h}ado*' ('waves')



(b) Spectrogram of [p + h] taken from the phrase '*kɨ ʧikap Hant^{h}e*' ('that purse Hante').

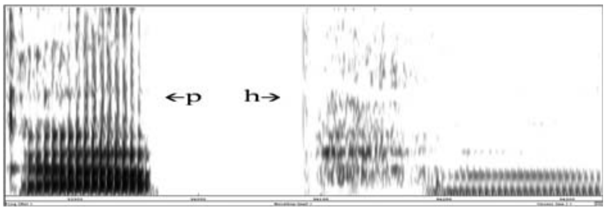


Figure 2. Spectrogram of [p^h] and [p + h]

Another question is whether the pattern is one of complete neutralization or whether the two categories remain acoustically distinct in the environment where they are reported to have the aspiration merger. There are several studies related with neutralization. As seen in Port and O'Dell (1983, 1985), the acoustic analysis of the neutralization of voicing in word-final position in German revealed that the distributions of acoustic parameter are significantly different, despite considerable overlap between the two categories. In their results, the vowel before the underlying voiceless obstruent was shorter than before the underlying voiced one. In addition, the aspiration on release of the voiceless stops was clearly stronger and lasted longer than for the corresponding voiced stops. Furthermore, the research of Port and O'Dell on the perception of word-final German

3) /h/ is included in the phonemes of Korean. Korean phonologists assume that there is /h/ in the coda such as /coh/ 'good' and /noh/ 'lay'. However, since only the unreleased consonants are allowed in the coda, the underlying /h/ in the coda is realized as [t˺]. Therefore, it is not possible to demonstrate the coalescence of /h/-plus-stop in the acoustic-based study because there is no actual realization of /h/. So, this study will be based on the coalescence of lenis stop-plus-/h/.

4) About the timing of gestures relative each other, Browman and Goldstein (1986, 1989) proposed that a gestural score specifies the sets of values of the dynamic parameters for each gesture and the temporal intervals during which each gesture is active.

obstruents showed that listeners discriminate between derived and underlying voiceless obstruents better than chance. The results provide the evidence that speakers maintained some small degree of difference between the two classes of obstruents and the fine phonetic detail of the incompletely neutralized contrast are perceptible in the neutralizing context.

However, Fourakis and Iverson (1984) claimed that the findings in Port and O'Dell (1983) were reflections of hypercorrection in the linguistically artificial environment of the phonetics laboratory. They proposed that in more natural linguistic contexts, the neutralization is indeed complete.

Likewise, from the phonetic study of the Aspiration Merger, I find out whether lenis stop-plus-/h/ is completely neutralized into aspirated stop in word-medial position or whether the two categories remain acoustically distinct in that environment. By comparing the phonetic characteristics of lenis stop-plus-/h/ to those of underlying aspirated stops, it is possible to examine whether the phonetic properties of the derived aspirated stop from lenis stop-plus-/h/ are similar to those of underlying aspirated stop. The experiment in this study can provide phonetic evidence for the described pattern of the Aspiration Merger, which was based on the transcription-based studies.

3. Experiment

Löfqvist (1980) mentioned that in stops, the timing of glottal opening during the closure is part of the mechanism controlling aspiration. Kingston (1990) claims that the amount that intraoral air pressure is elevated behind the stop closure together with the size of the glottal aperture determines the acoustic characteristics of the explosive burst of noise that occur when the stop is released.

The timing difference between /p + h/ and /p^h/[5] is expected to be reflected in the duration of the noise and the velocity of intensity build-up before the release. In /p^h/, the glottal spreading gesture peaks around the release, while in /p + h/, it would be expected to lie in the /h/. So, it would lead to a shorter aspiration period relative to the stop release in the former compared to the latter. If lenis stop-plus-/h/ is realized as an aspirated stop, it is expected to have shorter noise duration than the separate realization of lenis stop-plus-/h/. To be short, it is hypothesized that in the APP, the noise duration in /p + h/ is longer than that in the underlying aspirated stop, but not in the PPM.

5) To distinguish the underlying segments, I use phonemic symbol, / / in this paper.

The larger the glottal aperture and the lower the fold tension, the more glottal resistance will be reduced, the more air will flow through the glottis, and the more rapidly air pressure will rise in the oral cavity behind the obstruent articulation. The acoustic character of the burst reflects the size of the pressure build-up behind the obstruction. Kingston (1990) claimed that the timing of the laryngeal spreading gesture in an aspirated stop maximizes the acoustic effect of this gesture, since it maximizes the pressure build-up and air flow at the point of stop release. Since spreading the glottis occurs during the closure and it maximizes airflow up into the supralaryngeal vocal tract, /p^h/ is expected to have greater pressure build-up during closure than /p + h/. Contrary to /p^h/, in /p + h/, the spreading gesture follows the release of the closure and it isn't able to build up the amount of air flows as in /p^h/. That is, since the change of intensity shows the relative energy at the noise onset, it is expected to be greater in /p^h/ than in /p + h/. So, I hypothesize that in the APP, the change of intensity at the noise onset in /p + h/ is smaller than that of the intensity in /p^h/, but not in the PPM.

Lastly, I consider the effect of Aspiration Merger on the syllable structure. With regard to preceding vowel duration, vowels in open syllables are generally longer than those in closed syllables (Maddieson, 1985). In the sequence of /p + h/, the Aspiration Merger may affect the duration of the preceding vowel. If /p + h/ become a single aspirated stop, the derived aspirated stop becomes an onset of the following syllable and the preceding syllable changes into an open syllable. However, if /p + h/ is not realized as an aspirated stop, the stop is placed in the coda of the preceding syllable and /h/ becomes an onset of the next syllable. Since the preceding vowel duration is subject to variation depending on the Aspiration Merger, this measurement could distinguish /p + h/ from /p^h/ with and without the Aspiration Merger. Therefore, I hypothesize that in the APP, /p + h/ have shorter preceding vowel duration than /p^h/ but not in the PPM.

3.1 Speakers

Six Korean speakers, three males and three females, participated in this experiment. All of them were native speakers of the Seoul dialect. Their ages ranged from 25~45. They were recruited from the graduate students at the University of Texas at Austin. None of the speakers had any known speech or hearing disorders.

3.2 Speech Material

To examine the phonetic properties of the Aspiration Merger, I compare lenis stop-plus-/h/ to the underlying aspirated stop with and without the Aspiration Merger between APP and PPM positions.

All of the test sentences consisted of 10 syllables. The phonation of target stop is lenis in stop-plus-/h/ but aspirated in the underlying aspirated stops' group. Since the degree of aspiration in stop consonants varies according to the place of articulation of the stop and the nature of a following vowel (Löfqvist, 1976), I control the place of articulation of stops as bilabial ones and the following vowel as a low vowel [a]. Therefore, there are two segment types (/p + h/ and /p^h/ in intervocalic position), and two different positions (APP and PPM) in this experiment.

For each of the 6 speakers, 80 sentences were recorded (20 sentences x 2 segment types x 2 prosodic positions), for a total of 480 tokens.

In the group of /p + h/ in APP, /p/ is placed in the final position of the first PP and /h/ is placed in the initial position of the second PP as in (3a). In the group of /p + h/ in PPM, the target lenis stop and /h/ are placed within the same PP and /p/ is placed in the word-final position and /h/ is placed in the following word-initial position as in (3b).

In /p^h/ in APP, /p^h/ is placed in the initial position of the second PP as in (4a), while in /p^h/ in the PPM, /p^h/ is placed in the word-initial position within the first PP as in (4b). The target underlying segments are underlined below.

(3) /p + h/

(a) APP: [IP [PP kɨ munkap] [PP Hant^{h}e-nɨn sirə-he]]
That stationery case Hante-Top dislike-do
'Hante dislikes the stationery case.'

(b) PPM: [IP [PP Pjuŋkap hakseŋ-kwa] [PP pap-ɨl mək-ə]]
Pyungkap student-with a meal-ACC eat-ending
'With Pyungkap, (I) have a meal.'

(4) /p^h /

(a) APP: [IP [PP Kɨnjə-ka] [PP p^{h}ado-lɨl ʧoa-he]]
she-Nom waves-ACC like-do
'She likes waves.'

(b) PPM: [IP [PP Pata p^{h}al-ɨn] [PP aʧu kil-əs'ə]
Pata arms-Top very long-past ending
'Pata's arms were very long.'

3.3 Procedure

Subjects were asked to read materials written in Korean orthography, at a natural speaking rate throughout the recording session. The test sentences were presented in random order on separate slides in a timed PowerPoint presentation on an IBM laptop. Speakers were recorded in a sound-proofed booth, using solid state recorder, Maranz PMD 670 in the UT at Austin Phonetics Laboratory. Recorded materials were digitized at a sampling rate of 22,050 Hz.

3.4 Measurements

I measured the duration of noise, the change of intensity at the noise onset and the preceding vowel duration to find the differences between /p^h/ and /p + h/. The noise duration was measured from the point of release of noise or aperiodic wave to onset of periodicity in waveform.

The change of intensity at the noise onset has not been researched in previous acoustic studies. At the noise onset, energy values (dB) were measured at the point 10 ms. before the noise onset and at the point, 10 ms. after the noise onset in the intensity profile. The change of intensity at the noise onset was calculated by computing the difference between the two values.

Lastly, the preceding vowel duration was measured from the point in the expanded waveform at which wave amplitude and complexity begin to rise to the point where the decline in wave amplitude and complexity end. The measured vowel duration includes the release noise of preceding consonants.

4. Result

A repeated measures analysis of variance (ANOVA) was performed with two within-subjects factors (segment and prosodic position) using SPSS 16.

4.1. Noise Duration

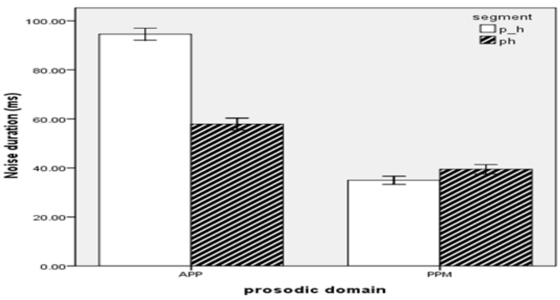


Figure 3. Noise duration by prosodic position * segment type[6]

In Figure 3, noise durations of /p + h/ are compared to those of /p^h/ within the different prosodic positions such as the APP and PPM. /p + h/ in the APP has longer noise duration than /p + h/ in the PPM, /p^h/ in the APP and PPM. While there is great difference between /p + h/ and /p^h/ in the APP, the two groups show rather small difference in the PPM position.

Results of a repeated measures analysis of variance (ANOVA) on noise duration show significant main effects for segment and prosodic position (F(1, 5)=18.223, p=.008 for segment; F(1, 5)=35.576, p=.002 for prosodic position). There is also significant interaction between segment and prosodic position (F (1, 5)=56.690, p=.001).

Pairwise post hoc comparisons reveal that /p + h/ in the APP is significantly longer than /p + h/ in the PPM (p<.0001), /p^h/ in the APP (p=.031), and /p^h/ in the PPM (p=.001). However, it is found that /p + h/ in the PPM is not significantly different from /p^h/ in the APP (p=.253) and in the PPM (p=.981).

The result in the noise duration supports the hypothesis that in the APP, /p + h/ has significantly longer noise duration than /p^h/ and that /p + h/ shows significant difference between the APP and PPM. Since in the PPM, /p + h/ does not have significant difference with /p^h/, this result reveals that /p + h/ is completely neutralized into aspirated stop in the medial position of the PP.

4.2 Change of Intensity at the Noise Onset

Figure 4 presents change of intensity in /p + h/ and /p^h/ in the APP and PPM. It is seen that the change of intensity in /p + h/ in the APP is smaller than any other groups. The difference in change of intensity between /p + h/ and /p^h/ is greater in the APP than in the PPM.

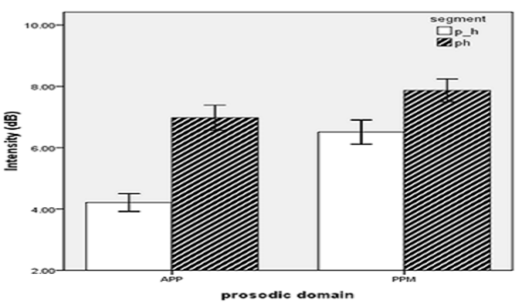


Figure 4. The change of intensity by prosodic position * segment type

The main effects for segment and prosodic position are found to be significant (F(1, 5)=53.439, p=.001 for segment; F(1, 5)=13.742, p=.014 for prosodic position).

The results show that the timing of the laryngeal spreading gesture in /p + h/ in APP is different from that of /p^h/. The smallest change of intensity in /p + h/ at the APP reveals that /p + h/ and /p^h/ make different build-ups of pressure and amount of air flow at the point of the release. Since /p + h/ shows great difference in the change of intensity between the APP and PPM, we can assume that the timing of the laryngeal spreading gesture for /p+ h/ is different depending on prosodic phrasing. However, since the interaction between the segment and prosodic position is not found to be significant (F(1, 5)= 2.908, p=.149], it is not possible to prove whether the change of intensity in the two categories shows complete neutralization in the PPM.

4.3 The Preceding Vowel Duration

Figure 5 illustrates preceding vowel durations of /p + h/ and /p^h/ in the APP and PPM. It is seen that /p + h/ and /p^h/ have longer preceding vowel duration in the APP than in the PPM and /p + h/ and /p^h/ don't show difference in the preceding vowel duration in the PPM.

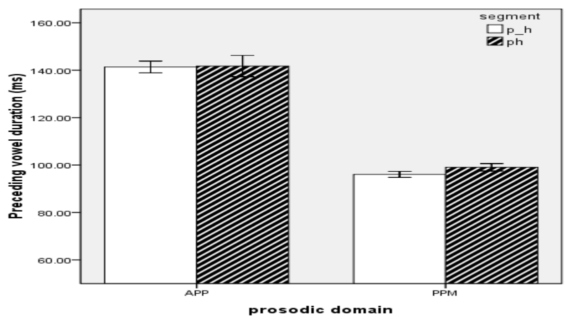


Figure 5. Mean preceding vowel duration by prosodic position * segment type

The main effect for prosodic position is significant but the effect of segment is not significant (F(1, 5)=.030, p=.870 for segment; F(1, 5)=42.349, p=.001 for prosodic position). The interaction between segment and prosodic position is not found to be significant (F(1, 5)=.064, p=.810).

The results of the preceding vowel duration do not support the hypothesis because /p + h/ in the APP does not have shorter preceding vowel duration than /p^h/ and /p + h/ in the PPM. They present opposite results from that which was expected before and do not show the effect of Aspiration Merger to the preceding vowel duration. Instead, both groups show phrase final lengthening in the PP. This will be discussed in section 5.

6) In the figure, 'ph' represents an aspirated stop.

5. Discussion

This study was designed to investigate the phonetic properties of the Aspiration Merger in Korean. In the results in the noise duration and change of intensity, the difference between /p + h/ and /p^h/ was greater in the APP than in the PPM. The results in the noise duration provided evidence supporting the hypothesis that /p + h/ is completely neutralized into /p^h/ in the PPM. In previous studies, the sound change in the Aspiration Merger was just explained by the coalescence of two segments. However, from the results of present study, it is possible to claim that /p + h/ and /p^h/ have physical similarity but that in the APP, there are different timing of gestures between them. That is, the vocal fold spreading gesture and closing phase of the gesture are earlier in /p^h/ and /p + h/ in the PPM than /p + h/ in the APP. In addition, the great difference in the noise duration and change of intensity of /p + h/ between the APP and PPM shows that the neutralization is sensitive to the phonological phrasing. However, the results from the preceding vowel duration fail to show the neutralization of /p + h/ into /p^h/ in PPM position.

In addition to the phonetic properties of the Aspiration Merger, this study gives us several previously unknown properties. In the results of noise duration, /p^h/ in the APP was found to have significantly longer noise duration than /p^h/ in the PPM. This result can be explained by the domain initial strengthening. Jun, Beckman and Lee (1998) observed variations in the glottal opening area using a fiberscopic technique, and claimed that for the voiceless aspirated stop, the glottal opening was longer phrase-initially than phrase-medially. It was also confirmed by many studies about the enhanced properties of phrasal-initial stops in Korean (Cho and Keating, 2001; Jang, 2009). Therefore, the differences in the noise duration for /p^h/ in the APP and PPM can support the domain-initial strengthening in the initial position of the PP.

In the results of the preceding vowel duration, both /p + h/ and /p^h/ show longer vowel duration in the APP than in the PPM and there is no contrast of /p + h/ and /p^h/ between the APP and PPM. In order to explain the long vowel in phrase-final position, we need to consider several possibilities. First, it may be explained by the effect of the position in the phrase. One of the effects on vowel duration is that vowels at the end of a domain (utterance, intonation phrase, prosodic word) are longer than corresponding non-final vowels (Myers and Hansen, 2007). In English (Klatt, 1975), the effect is stronger in those domains that are higher in the prosodic hierarchy (Utterance > Intonation Phrase > Prosodic word). In Korean, several previous studies reported significant durational difference between the intermediate phrase (Accentual Phrase or Phonological Phrase)-final and Word-final vowels (Cho and Keating, 2001; Jang, 2009). However, in Jun (1993, 1998), it was reported that AP-final lengthening was not found in Korean. In order to find out the reason why syllable structure-sensitive vowel duration was not found in the current study, it is necessary to consider other possibilities to explain the results.

Another possibility is that Korean does not have shorter vowels in closed syllables than in open syllables. However, assuming that CVC syllables are heavy syllables and CV syllables are light in Korean, Lim (2001) suggested that the mean vowel duration of light syllable (e.g. *ma.na.gwa* ‘the capital of Nicaragua’) was significantly longer than that of heavy syllables (e.g. *mal.jang.nan* ‘joke’). In addition, he showed that the final vowel of the light and heavy syllable in the Accentual Phrase is significantly longer than the previous vowels in the AP. Since Korean has shorter vowel in closed syllables than in open syllables, it is possible to claim that there is such an effect of Aspiration Merger on the preceding vowel length but that it is overwhelmed by the much more influential effect of phrase-final lengthening.

Even though this study provides phonetic evidence for the described pattern of Aspiration Merger in Korean, a further elaborated perception study will be needed. To prove the characteristics of neutralization of the two categories, we also need to investigate whether native speakers distinguish the derived aspirated stop from the underlying aspirated stop. From such a perception experiment, we can find out how native speakers categorize the derived aspirated stops in different prosodic domains.

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Appendix: Sample Stimuli

1. /p + h/

a. APP

kɨ ʧikap Hant^he-nɨn sirə-he.
That purse Hante-Top dislike-do
'Hante dislikes the purse.'
kɨ ʧ^hopap Hansu-nɨn sirə-he.
That sushi Hansu-Top dislike-do
'Hansu dislikes the sushi.'
kɨ ʧaŋkap Hanmu-nɨn sirə-he.
those gloves Hanmu-Top dislike-do
'Hanmu dislikes those gloves.'
kɨ kimpap Hant^he-nɨ n sirə-he.
That Kimpap Hante-Top dislike-do
'Hante dislikes the Kimpap.'
kɨ jakpap Hanmu-nɨn sirə-he.
That sweet rice dish Hanmu-Top dislike-do
'Hanmu dislikes the sweet rice dish.'

b. PPM:

jəŋkap haks'eŋ-kwa pap-ɨl mək-ə.
Youngkap student-with meal-ACC eat-verbal ending
'With student Youngkap, (I) have a meal.'
ʧekap haks'eŋ-kwa pap-ɨl mək-ə.
Jekap student-with meal-ACC eat-verbal ending
'With student Jekap, (I) have a meal.'
ʧinkap haks'eŋ-kwa pap-ɨl mək-ə.
Jinkap student-with meal-ACC eat-verbal ending
'With student Jinkap, (I) have a meal.'
junkap haks'eŋ -kwa pap-ɨl mək-ə.
Yunkap student-with meal-ACC eat-verbal ending
'With student Yunkap, (I) have a meal.'
Pyuŋkap haks'eŋ -kwa pap-ɨl mək-ə.
Pyungkap student-with meal-ACC eat-verbal ending
'With student Pyungkap, (I) have a meal.'

2. /p^h/

a. APP:

Kɨ namʧa-ka p^hama-lɨl he-s'ə.
That man-Nom perm-ACC do-past ending
'That man had a perm.'
Kɨ jəʧa-ka p^haka-lɨl ip-ə.
That woman-Nom parka-ACC take-verbal ending
'That woman takes parka.'
Kɨ sonjə-ka p^hasɨ-lɨl sat-s'ə.
That girl-Nom cataplasm-Acc buy-past ending
'That girl bought a cataplasm.'
Sonjə -ka p^hado-lɨl ʧoa-he.
Girl-Nom waves-ACC like-do
'The girl likes waves.'
Sonjə -ka p^hapsoŋ-ɨl ʧoa-he.
Girl-Nom popular music-ACC like-do
'The girl likes popular music.'

b. PPM:

pata p^hal-ɨn aʧu kil-əs'ə.
Pata arms-Top very long-past verbal ending
'Pata's arms were very long.'
ʧuŋ-ka p^hal-ɨn aʧu kil-əs'ə.
Jung-suffix arms-Top very long-past verbal ending
'Jung's arms were very long.'
pata p^han-ɨn aʧu kil-əs'ə.
Pata plate-Top very long-past verbal ending
'Pata's plate was very long.'
ʧe-ka p^han-ɨn aʧu kil-əs'ə.
Jeka plate-Top very long-past verbal ending
'Jeka's plate was very long.'
Kim-ka p^han-ɨn aʧu kil-əs'ə.
Kim-suffix plate-Top very long-past verbal ending
'Kim's plate was very long.'