Phonetic grounding of position and height asymmetries in hiatus resolution: An acoustic analysis of Korean VV sequences*

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Kang, Hijo. 2013. Phonetic grounding of position and height asymmetries in hiatus resolution: An acoustic analysis of Korean VV sequences. *Studies in Phonetics, Phonology and Morphology* 19.2. 217-232. This paper deals with two typological patterns in hiatus resolution, position and height asymmetries, from the perspective of phonetics and phonology interface. In languages where hiatus is disfavored in the output, the weakening of a vowel is more likely to take place in V_1 and high vowels than V_2 and non-high vowels, respectively. Assuming that these typological asymmetries are rooted in the acoustic and auditory mechanisms of human speech (Ohala 1993), I conducted an acoustic analysis of Korean VV sequences, which were recorded by six Korean speakers in two different speech rates. The results showed that the steady state of V_1 is shorter than that of V_2 in CV_1V_2 words but not in CVCV words. High vowels turned out to have shorter steady states than non-high vowels and the proportional difference increased in fast speech. These results suggest that the typological patterns are not only morphologically motivated (e.g., Casali 1996) but phonetically grounded. **(Seoul National University)**

Keywords: Hiatus resolution, position and height asymmetries, phonetic grounding

1. Introduction

This paper is concerned with two crosslinguistic asymmetries in hiatus resolution, presented in the studies of Casali (1996) and Rosenthall (1997). They found that hiatus resolution such as vowel deletion or gliding is more likely to occur in V_1 (position asymmetry) and high vowels (height asymmetry) than in V_2 and non-high vowels, respectively. They suggest universal constraints and rankings to account for the asymmetries in the framework of Optimality Theory (Prince and Smolensky 1993), which is regarded as an analytic bias approach (Wilson 2006, Moreton 2008). In this approach, typological patterns are assumed to result from cognitive biases such as universal grammar, which facilitate the acquisition of the typological patterns rather than others.

This paper takes another approach to the typological patterns, which is called channel bias approach (Ohala 1993, Blevins 2004). In this approach, typological patterns are the results of recurrent diachronic changes, which are mainly caused by human articulatory and/or auditory mechanisms. Following this approach, I hypothesize that the two asymmetries in hiatus

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resolution start from phonetic variation in the ordinary speech of VV sequences. If a phonetic 'perturbation' is not corrected properly in perception, a hypo-correction could occur and it could result in a sound change such as phonologization of vowel elision or glide formation. As first step to link the synchronic variation and the phonological pattern, a set of acoustic data on Korean VV sequences is presented and analyzed in this paper. The results show that V_1 in these sequences is consistently shorter than V_2, which corresponds to the positional asymmetry in Casali (1996). When it comes to the height asymmetry, this paper reports that high vowels are not only shorter than non-high vowels, but more reduced in fast speech, compared to their durations in slow speech.

In the next section, after presenting the typological asymmetries, the hypotheses are presented with previous studies which provide the phonetic basis for the hypotheses. In section 3, the methods and results of a production experiment on Korean VV sequences, which was conducted to test the hypotheses presented in section 2, are provided. In section 4, the results are discussed, focusing on what should be done in the future.

2. Previous research

2.1 Crosslinguistic findings

Casali (1996, 1997) surveyed 68 Niger-Congo and 19 non-Niger-Congo languages which have vowel elision in at least one context. The survey concludes that V_1 elision is far more common and productive than V_2 elision in terms of frequency of occurrence (85 vs. 30). Furthermore, V_2 elision implies V_1 elision with only two exceptions. V_2 elision occurs only when it belongs to a function word or a suffix and V_1 belongs to a lexical word or a root. In other words, V_2 elision is exclusively morphologically driven. This generalization is well represented in Chichewa (a Bantu language spoken in Malawi, Casali 1996:31), where V_1 elision and V_2 elision are both found.

(1) V_1 and V_2 elisions in Chichewa (Casali 1996: 31-4)
a. V_2 elision with demonstrative suffixes
i) mwana-uyo ➔ mwanayo 'that child'
child-that
ii) bambo-awa ➔ bambowa 'this man'
man-this
b. V_1 elision in prefixes
i) si-u-pita ➔ supita 'you will not go'
NEG-you-go
ii) ti-a-bwela ➔ tabwela 'we have come'
we-PERF-come
c. V_1 elision in a stem plus a VCV suffix
i) umba-idwa ➔ umbidwa 'be moulded'

mould-PASS
ii) omba-edwa ➔ ombedwa 'be slapped'
slap-PASS
d. V_1 elision in a passive suffix plus a causative suffix
i) mang-a-itsa-idwa ➔ mangitsidwa 'cause to get arrested'
ii) pond-a-edwa-esta ➔ pondedwetsa 'cause to be stepped on'

V_2 elision is confined to demonstrative suffixes which have the form of VCV as in (1a). In contrast, V_1 elision takes place in many morphological environments (1b to 1d). To account for his finding, Casali proposes the universal constraint rankings in (2).

(2) Universal rankings about hiatus resolution (Casali 1996: 31, 137)
a. PARSE(F)-$[_W$ >> PARSE(F) (MAXWI >> MAX in Casali 1997)
b. PARSE(F)-lex >> PARSE(F) (MAXLEX >> MAX in Casali 1997)

The ranking in (2a) accounts for the prevalence of V_1 elision, when hiatus takes place due to the combination of morphemes. While V_1 elision occurs irrespective of the morphological status of the vowels, V_2 elision is only morphologically driven, depending on the constraints and their ranking in (2b).

Rosenthall (1997) presents additional typological findings on hiatus resolution, which are given in (3). The focus was on the distribution of surface results of underlyingly prevocalic vowels (or V_1s) such as deletion, glide formation, and epenthesis. The generalizations in (3) imply that if a prevocalic vowel is weakened, high vowels should be the first.[1]

(3) Generalizations on the relation between distribution and vowel height (Rosenthall 1997: 140)[2]
a. If a high vowel has a distribution (other than glide formation), other vowels have the same distribution.
b. If mid vowels have non-moraic counterparts, so must high vowels.

The two typological studies above can be generalized as two asymmetries in hiatus resolution: position and height asymmetries. They are presented in (4).

(4) Two asymmetries in hiatus resolution
a. Position asymmetry: If hiatus is resolved by the weakening of one vowel, V_1 is more likely to be weakened than V_2.
b. Height asymmetry: If hiatus is resolved by the weakening of one vowel, high vowels are more likely to be weakened than non-high

[1] In this paper, 'vowel weakening' is defined as 'losing nucleus status in syllabic structure'.
[2] In Rosenthall (1997), there is another generalization: languages exhibit at most two outcomes of prevocalic vowels.

vowels.

It is not the case that weakening of high V_1 takes place only next to a morphological boundary. In language change, glide-formation of V_1 is very common even within morphemes, in particular when V_1 is high (Millar 2007: 80). Chitoran and Hualde (2007) found that the diphthongization of *iV* sequences (e.g., *iV* ➔ *jV*) in Romance languages has occurred within morphemes when the language had diphthongs from other sources such as loanwords and/or when the first vowel, *i*, is not lengthened prosodically (e.g., French and Spanish). So historical linguistic data lead us to the question of how we could account for cases where morphology has nothing to do with hiatus resolution, since here V_2 is not an initial segment of any morpheme or word as in Casali's proposal. Even synchronically, languages have vowel hiatus without morphological conditioning. We will consider a variety of hiatus resolution strategies in Korean in the next section, focusing on 'within-morpheme' phenomena.

2.2 Hiatus resolution in Korean

Basically, Korean speakers use different strategies depending on the categories of words. Glide formation, glide insertion, and deletion (in particular, /ɯ/, irrespective of its position) are applied in verbal suffixation and conjugation. In nouns, glide formation (underlined, e.g., *tɕuin~tɕwin* 'owner'), elision (**bold**, e.g., *maum ~ mam* 'heart'), and coalescence (*italic*, e.g., *ai ~ e* 'child') are optionally adopted, as shown in Table 1.[3]

Table 1. The realization of hiatus within nouns in Korean (Kim 2000, Chung 2007)
***Shaded cells represent 'no change or no hiatus resolution'.**

V_1 \ V_2	i	ɯ	u	e	o	ʌ	a
i			iu~ju	ie~je	io~jo	iʌ~jʌ	ia~ja
ɯ							
u	ui~wi			ue~we		uʌ~wʌ	ua~wa
e		eɯ~**e**					
o	oi~*we*	oɯ~**o**					
ʌ	ʌi~*e*	ʌɯ~**ʌ**					
a	ai~*e*	aɯ~**a**					

While Kim (2000) employs different constraint rankings to explain speech

3 Korean does not have many cases of hiatus in nominal declension because the most frequently used case markers have allomorphs. For example, the nominal case marker is realized as *–i* after a consonant and as *-ka* after a vowel. When a case marker does not alternate, glide insertion optionally takes place (e.g., *ɯide-e* [ɯideje] 'medical school-LOC').

rate effects on hiatus resolution, Chung (2007) attempts to explain the variety of hiatus resolution in Korean by adopting rules and repairs. Although Kim (2000) and Chung (2007) are concerned with language-specific data on hiatus resolution, they take the same approach as Casali (1996, 1997) and Rosenthall (1997) in that they view hiatus resolution as involving 'phonological' processes.

In this study, I hypothesize that the aforementioned typological patterns are phonetically grounded, since some hiatus resolutions occur irrespective of morphological environments, which means the prevalence of V_1 elision or glide formation is purely driven by position, not by morphological status. The fact that hiatus resolution is sensitive to speech rates (e.g., Korean hiatus resolution, Kim 2000) also supports this hypothesis. Indeed, Van Heuven and Hoos (1991) show that glide insertion, as a means of hiatus reolution in Dutch, is not a phonological process but a phonetic one. They conducted a production and a perception experiment showing that glides [j] and [w] which surface due to glide insertion in Dutch are different from 'underlying' glides. On the basis of the results, they argue that there is no glide insertion rule in the phonology of Dutch.

Assuming that hiatus resolution is phonetically grounded, I speculate that phonetic details of hiatus will provide phonetic clues to the source of the typological patterns. In other words, even when hiatus is not resolved, the phonetic realization of VV sequences is expected to show the possibility of misperception, and moreover, phonologization. According to the channel bias approach, such details should be the starting point of any kind of sound change leading to phonological hiatus resolution (Hyman 1976, Ohala 1993, Blevins 2004).

On the basis of the typological patterns in Casali (1996, 1997) and Rosenthall (1997), I provide the hypotheses in (5). In this study, speech rate is manipulated as a means of inducing variation which may be related to sound change.

(5) Hypotheses concerning hiatus
  a. Hypothesis I: In fast speech, the steady state of V_1 will be reduced more than that of V_2.
  b. Hypothesis II: In fast speech, the steady state of high vowels will be reduced more than that of non-high vowels.

Definitely, the weakening of a vowel in the two asymmetries in (4) involves 'shortening' of its duration, considering that the reduction was exemplified as non-moraic realization of vowels such as glide formation or elision (note that gliding occurred in Romance languages when a prevocalic *i* was not lengthened). So Hypotheses I and II are related directly to the position and height asymmetries in (4). In the next section, we will review relevant literature on the phonetics of vowel sequences as basis for the hypotheses and the experiment.

2.3 Phonetic studies on vowels

Unfortunately, there are few phonetic studies on hiatus. Whether it is a phonological or a phonetic process, we need to know what is really occurring in the realizations of vowel sequences. As Kim (2000) points out, speech rate influences the ways vowel sequences are realized. Gay (1968) investigates how English diphthongs vary according to different speech rates. First, he measured the durations of onset steady state, glide, and offset steady state of /ɔɪ/, /aɪ/, /aʊ/, /eɪ/, and /oʊ/ in slow, moderate, and fast speech. It was found that in fast speech, onset and/or offset steady states are negligible or absent and that glide durations are longer than both onset and offset regardless of speech rates. In other words, the duration of glide is robust while those of onset and offset steady states are subject to change. Second, the formant properties of diphthongs were also revealed to be influenced by speech rate. In general, the faster the speech is, the shorter the distance between onset and offset in the vowel space (for F1 and F2) are. Specifically, the formant variation of offset state is very large compared to that of the onset state. Based on the results, it was concluded that the two crucial features of diphthongs are onset frequency (formants, the starting point in vowel space) and second-formant rate of change (the direction of change).

With these results and conclusion, Gay (1970) conducted perception experiments where onset/offset formants or durations of English diphthongs were manipulated. The stimuli were perceived as diphthongs even though they did not have any initial or terminal steady states. In terms of duration, the shifts from monophthongs to diphthongs occurred between 130 and 180ms. The results show that the specific course of the glide, rather than the locations of the targets, serves as the primary distinguishing cue for each diphthong and that transitional duration rather than change in frequency provides the primary cues for separating vowels and diphthongs.

Though English diphthongs are distinguished from hiatus in that they take only one nucleus position, I expect that an acoustic analysis on hiatus would produce similar results since both vowel sequences and diphthongs involve sequences of vocoids. As the onset and offset steady states are reduced or disappear in fast speech, the steady states of vowels in hiatus are also expected to be reduced. Will the reduction occur in both steady states (i.e., V_1 and V_2) at the same rate? I expect that V_1 reduction will be more extensive than V_2 reduction, based on the typological tendency described in section 2.1. Also, note that the onset steady states, as well as the offset steady states, were drastically reduced in English diphthongs, though the first vocoid target (e.g., /ɔ/ in /ɔɪ/) is considered a nucleus. This implies that the steady states in hiatus could also be reduced or totally lost even though each vowel is parsed under a nucleus.

In sum, acoustic studies of vowels show that the duration of steady states in VV sequences varies drastically depending on speech rate. On the basis of the previous research and the hypotheses in (5), I make specific predictions as follows:

(6) Predictions

a. SS_1 (the steady state of V_1) will be shorter than SS_2 (the steady state of V_2) in fast speech, but not in slow speech. If SS_1 is shorter than SS_2 in slow speech, the difference between the proportions of SS_1 and SS_2 will be bigger in fast speech. (Statistically, a significant interaction of rate and position)

b. SS_1 of a high vowel will be shorter than SS_1 of a non-high vowel and the difference will be greater in fast speech than in slow speech. (Statistically, a significant interaction of rate and height)

To see whether these predictions are correct or not, Korean was selected as test language. As we saw in section 2.2, Korean has many cases where underlying hiatus is realized as VV without hiatus resolution. More importantly, Korean does not have lexical stress, which has a strong effect on vowel length. In the next section, I will describe the experiment in detail.

3. Experiment

3.1 Methods

The materials for acoustic analysis were bisyllabic words containing VV sequences. Out of 7 monophthongs in Modern Korean (/i/, /ɯ/, /u/, /e/, /o/, /ʌ/, and /a/), 6 vowels excluding /ɯ/ were adopted for both V_1 and V_2.[4] Combined with word-initial /p'/, the vowels produced 30 target nonce words (*p'V₁V₂*, 6 vowels for V_1 × 5 vowels, excluding the same vowel as V_1, for V_2). Nine *p'V_1pV_2* (/i/, /u/, and /a/ for both V_1 and V_2) nonce words were adopted to compare the durational aspects of vowels in vowel hiatus and with those in CVCV sequences.[5] To compare VV sequences with and without a glide, four *p'V_1GV_2* (glide had the same features as the V_1 except that it is non-syllabic) nonce words were also included. In sum, the stimuli included 30 CV_1V_2 target words plus 9 CVCV and 4 CVGV control words. The total 43 words are listed in the appendix. A randomized list of 54 nonce words (including 11 fillers) was presented in written form, embedded in a sentence context, "*Mansuga* _____*-nɯn wegugʌrago malhet'a*." ("Mansu

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[4] The high back unrounded vowel /ɯ/ was excluded because 1) /ɯ/ is the weakest phonologically and phonetically, which means that it is deleted (Kim 2000) or inserted (Kang 2003) at the phonological level most often in Korean and that it is reduced to [ɯ̥] at the phonetic level (Lee 1996), 2) /ɯi/ is considered as the only diphthong in Korean (Lee 1996) so it could be realized differently from other VV sequences and 3) in a pilot experiment, its reduction made measurements impossible.

[5] Labial stops were selected for the stimuli following Beddor et al. (2002). The initial consonant was tense (*p'*), which have the shortest VOT period (Lee 1996) and the medial consonant in CVCV words was lax (*p*) because tense and aspirated consonants shorten the preceding vowel (Choi and Jun 1998).

said _____ is a foreign word.")[6]

Six native speakers of Korean (three female and three male) were recorded. All were born in Seoul, where so-called standard Korean is spoken. The range of age was 24 to 32 (average was 28) and their length of stay in the US was 6 months to 4 years. Subjects were paid for their participation.

Recording was done in a sound-attenuated room. The devices used for the recording were Marantz PMD 660 digital recorder and Shure SM 48 microphone. The utterances were recorded and digitized at a 44.1kHz sampling rate and 16-bit quantization. Speakers were requested to read the written sentences 'slowly and clearly but not syllable-by-syllable' three times and 'as fast as they could without noticeable errors' three times. After the instructions were given, speakers practiced reading sentences at both slow and fast rates. In total, 1,548 tokens (43 tokens × 2 rates × 3 repetitions × 6 speakers) were obtained from the recording.

Analysis was done using Praat (Boersma and Weenink 2005). Segmentation was done by means of visual inspection of waveforms and spectrograms, with the following criteria. Each target word ($p'V_1V_2$) was divided into three parts: SS_1, TP (transitional period), and SS_2. The onset of the V_1V_2 vocalic region (or SS_1) was the first peak of the periodic waveform after a stop burst. The offset of V_1V_2 (or SS_2) was marked at the last vocalic peak of the waveform before the more sinusoidal waveform of the following nasal. Then the onset of TP was marked where the stream of the first and/or second formant changed its direction abruptly. The offset of TP was determined in the same way. These were done on the basis of spectrographic display with an overlay of formant values computed by LPC analysis.[7] When there was no abrupt change, the spectrogram was enlarged focusing on F1 or F2 in question. The slope of formant curve (Hz/ms) was calculated and TP was defined where the absolute value of the slope is over 1 Hz/ms for F1 and 4 Hz/ms for F2. An example is given in Figure 1, where the onset and the offset of TP are relatively prominent.

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6 The fillers were presented mostly at the first and the last parts of the list since speakers tended to be the slowest at the beginning and the fastest at the end of the list in the pilot experiment.

7 The LPC analysis was set with 5ms window length, 50dB dynamic range, 100 dB/Hz maximum, 6.0dB/oct. pre-emphasis, and 0 dynamic compression.

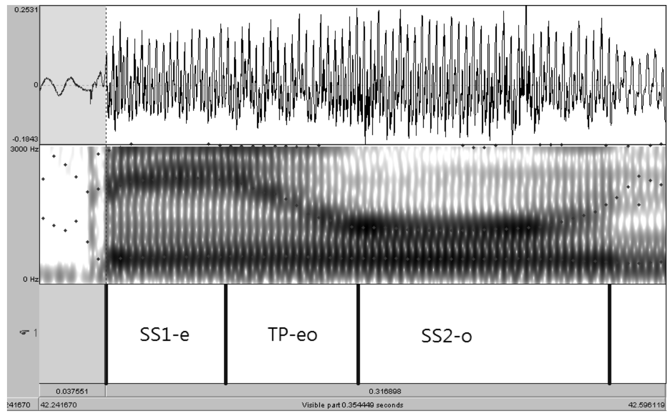

Figure 1. An example of segmentation for the word p'eo

As for CVCV words, the only additional criterion involved the offset of the first vowel. This was taken as the last peak of the periodic waveform before a closure.[8] As for CVGV words, as Shin (2000) points out, glides did not have any steady states. The onset and the offset of a glide were determined according to the same criteria as TP in VV sequences. During the segmentation, 15 tokens[9] (0.97%) were excluded because their formant structure did not show any observable change and 3 tokens[10] (0.19%) were discarded because the targeted vowels were not correctly articulated.

After segmentation, the duration of each part (V_1, TP/C/G, and V_2) was computed using a Praat script. The total duration of the three parts is referred to as 'word duration'.[11] The durational proportions were calculated on the basis of this word duration.

3.2 Results

An ANOVA was carried out on the word duration data. The first test, where speech rate was the only independent factor, confirmed that all the speakers used significantly different speech rates in the fast and slow conditions ($F(1,5)=34.07$, $p<.003$). The ratios (fast to slow) ranged from 0.40 to 0.72 and the average was 0.57.

8 Sometimes there was no clear-cut stop closure for the second consonant (lax bilabial stop). Then the offset of the first vowel was marked as the last peak that was higher than the following plateau waveform.

9 They include 7 of 'pou', 3 of 'puo', 2 of 'pʌo', 1 of 'poʌ' and 2 of 'pei'.

10 They include each of 'pubu', 'poo', and 'pʌʌ'.

11 Word-initial /p'/ was not included in the word duration.

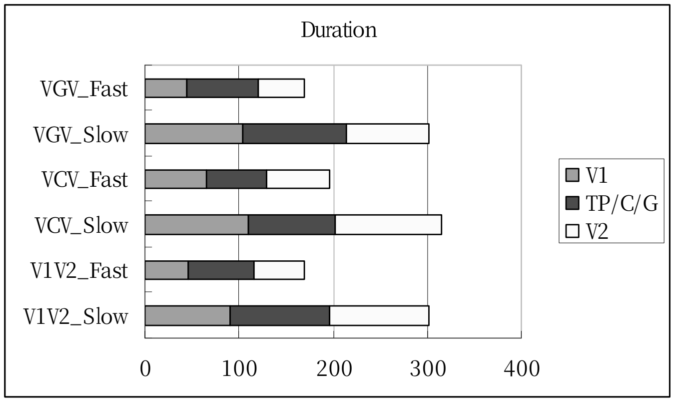

Figure 2. Duration of V1, TP/C/G, and V2 for three word types at two speech rates

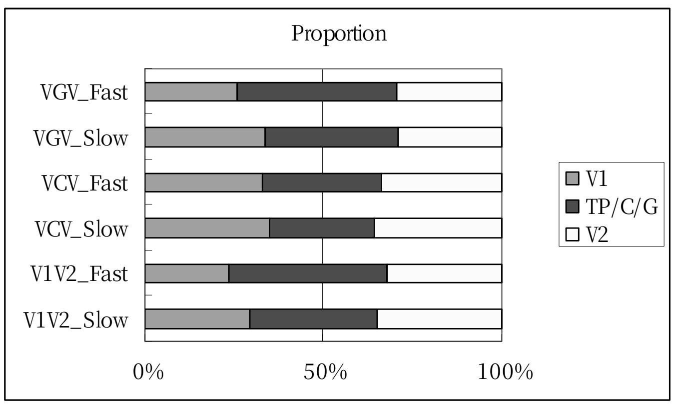

Figure 3. Proportion of V1, TP/C/G, and V2 for three word types at two speech rates

Having shown a speech rate effect, we now consider whether the effect is stronger for V_1 (Hypothesis I) and whether high vowels are more affected than low vowels (Hypothesis II). Figures 2 and 3 give segment and word durations in absolute (Figure 2) and proportionate (Figure 3) units. The data therein include the average durations of CV_1V_2, CVCV, and CVGV types for each speech rate. Figure 2 shows that speech rate has an effect on the duration of each part as well as on the duration of the word. Figure 3 gives an impression that CVCV is fairly well-balanced while CV_1V_2 is slightly inclined to the left.

It was hypothesized that SS_1 would be reduced more than SS_2 in fast speech (Hypothesis I). To test this hypothesis, a series of ANOVAs were performed on the durations and the proportions with factors such as position and rate, for each word type.[12] Hypothesis I is interpreted as an 'interaction of position and rate' statistically. In CV_1V_2 words, SS_1 was significantly shorter than SS_2 (F(1,5)=12.90, p<.02 for durations and F(1,5)=10.70, p<.03 for proportions). The steady states of vowels in hiatus were proportionally reduced in fast speech (29.6% (SD=1.86) ➔ 23.5% (5.28) for SS_1 and 34.7% (3.75) ➔ 32.1% (2.39) for SS_2). However, there was no significant interaction between rate and position (F(1,5)=1.52, p=.27), even though the direction of change was consistent with Hypothesis I. This means that SS_1 is shorter than SS_2 but it is not reduced in duration significantly more than SS_2 at fast rates. It seems that the duration asymmetry is unique to CV_1V_2 words. In CVCV words, proportions as well as durations were not different depending on the position of the vowel (F(1,5)=0.55, p=.49 for durations and F(1,5)=0.35, p=.58 for proportions). Speech rate made a significant difference in proportion (F(1,5)=21.42, p<.01). But there was no position asymmetry in CVCV words. The results of CVGV words seem hybrid. Position did not make a significant difference on its own (F(1,5)=1.81, p=.24 for durations and F(1,5)=0.04, p=.86 for proportions), but there was a significant interaction between rate and position (F(1,5)=8.04, p<.04). V_1 was longer than V_2 in slow speech but shorter in fast speech.

Table 2. The durations and proportions of SS_1, TP, and SS_2 in CV_1V_2 and CVGV words with same vowel pairs

		Duration				Proportion		
		SS1	TP	SS2	Total	SS1	TP	SS2
CV_1V_2	Mean	56.6	86.3	76.6	219.9	**23.8**	40.8	**34.6**
	StDev	35.6	30.6	34.8	79.7	11.1	11.8	9.5
CVGV	Mean	73.8	93.2	67.9	234.6	**29.7**	41.1	**29.2**
	StDev	44.3	31.7	28.3	85.4	9.5	9.6	7.7

An anonymous reviewer pointed out that the results of VGV sequence do not look different from those of V_1V_2 sequences in Figures 2 and 3 and suggested that the results be compared only with 4 vowel pairs, which were used for VGV sequences (CV_1V_2 words had more vowel pairs than CVCV or CVGV words). The comparison gave birth to the results as in Table 2. The results clarify the difference between the two word types. The proportions of SS_1 and SS_2 are symmetrical in CVGV words, while SS_1 is much short than SS_2 in CV_1V_2 words. This suggests that glide insertion may guarantee solid duration of V_1.

In statistics, Hypothesis I was not confirmed. However, it was found that V_1 is shorter than V_2, which was not found in other types of words.

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[12] Proportions were included since it has been noted that durational proportion in word is an 'invariant' property of vowel in Japanese and Swedish vowel length contrast, which is little affected by speech rate (Hirata 2004, Segerup 2000).

Table 3. The durations and the fast/slow ratios of SS_1 and SS_2 for each vowel height

position	height	Dur. at fast	Dur. at slow	fast/slow ratio
SS_1	high	39.7	82.4	0.48
	mid	46.8	96.1	0.49
	low	49.3	94.5	0.52
SS_2	high	49.0	103.3	0.47
	mid	56.5	112.8	0.50
	low	57.2	101.2	0.56

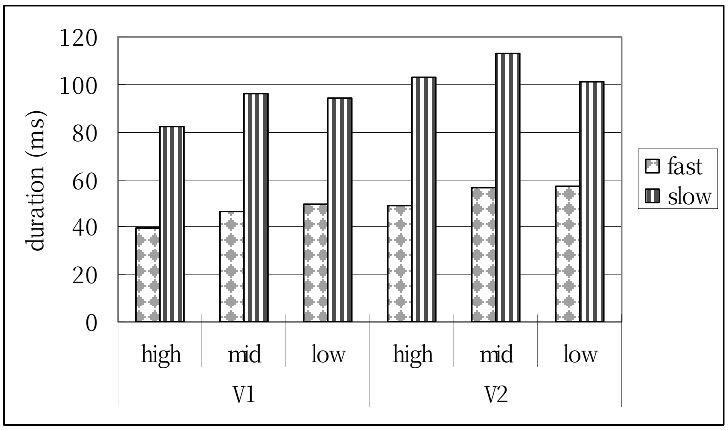

Figure 4. Durations of high, mid, and low vowels in V_1 and V_2 in two different speech rates

Hypothesis II states that a rate effect will be greater in high vowels than non-high vowels. An ANOVA tested the effect of vowel height as well as rate and position on the durations of steady states in CV_1V_2 words. SS_1 was the shortest when V_1 was high and the difference was significant ($F(1,5)=19.37$, $p<0.01$). The 'height' effect interacted with rate ($F(1,5)=7.16$, $p<0.05$). As predicted by Hypothesis II, steady state was reduced in fast speech more when the vowel was high than when it was not. Also, the interaction of all the three factors was significant ($F(1,5)=8.47$, $p<0.05$). The fast-to-slow ratios in Table 3 make clear the reason for this interaction. The reduction of high vowel duration/proportion is bigger in SS_2 than in SS_1.

4. Discussion

The results showed that V_1 (specifically, the steady state of V_1) is shorter than V_2 in CV_1V_2 words, which is not found in CVCV words. In addition, the positional effect was aggravated by speech rate, though the change was not statistically significant. The height of vowel, as expected, affected the reduction of vowels. The higher a vowel is, the more reduced it is in fast speech. All the results indicate that the typological asymmetries in hiatus resolution, by and large, match the phonetic patterns found in the realization of VV sequences in Korean. Though it is too early to conclude, the typological pattern might be developed from the phonetic variation. Specifically, a sequence like /ia/ is much more likely to be realized as [ja] or [a] than /ai/ would be realized as [aj] or [a].[13] Our acoustic analysis of Korean hiatus suggests some potential answers. The tendency for [i] to glide or to be lost may derive from the combined effects of the position and the height of the vowel. As Figure 4 above shows, high V_1 is the shortest of all the cases, irrespective of speech rate. From the viewpoint of articulation, it seems likely that the positional asymmetry be due primarily to anticipation. The articulation of V_2 starts before that of V_1 ends and this invasion is prominent when there are no intervening consonants. Consequently the duration of V_1 is short. This asymmetry is also found in CC clusters (Jun 2004: 68), which suggests that anticipation effect is stronger than carry-over effect in general. The height asymmetry seems, ultimately, due to the intrinsic disparity between high and non-high vowels (Lehiste 1970, high vowels are intrinsically shorter than low vowels). However, it remains unanswered why the anticipation effect and the intrinsic disparity have 'synergy' effect in the context of hiatus.

This study raises several interesting questions for future research. Above all, we need to know whether the acoustic patterns reported here are found in other languages. One logical language to conduct follow-up research on is Japanese, where glide insertion may occur depending on what the VV sequence is and otherwise, VV sequences are realized without hiatus resolution at the surface. Besides determining whether Japanese data will show similar patterns as Korean data, it would be interesting to see whether inserted glides are acoustically different from underlying glides and whether hiatus resolution (via glide insertion) will make a difference in the duration and/or formants of V_1. In other words, will glide insertion protect V_1 from acoustical weakening as in CVGV words in Korean? The second question is whether hiatus in fast speech, which has proportionately short or absolutely no SS_1, will be more prone to misperception than forms with longer SS_1.[14] It should be found under what acoustic conditions hiatus sequences are misperceived. The presence/absence of 'compensation' would be an additional variable in perception. The third question is whether real words will produce different results. Will the disparities between V_1 and V_2 and between high vowels and non-high vowels be widened? If so, a sound change could be accelerated.

As noted in section 2, hiatus resolution has been regarded as a

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[13] Rather, hiatus with non-high V_1 has often a coalescence as a way of resolution (for example, /ai/ is realized as [ɛ]), while that with high V_1 rarely has it (Casali 1996).

[14] Hyman (1976) notes "In order for a change to catch on (and become a phonological 'rule') it is necessary for it to be perceived and diffused throughout a speech community. In that way phonological change is *perception-oriented*, even though the seeds for a change may be articulatory."

phonological process in most research. As a result, the two asymmetries in hiatus resolution have been also considered as the results of universal grammar. However, the presence of phonological grammar does not imply the absence of the effects of articulatory/auditory mechanisms at the phonetic level and vice versa. This study showed that the acoustic variation reflects the very typological patterns, suggesting that the typological patterns could be the results of phonetic variation.

Appendix: Stimulus materials – Korean nonce words

CV_1V_2			CVCV	CVGV
p’iu	p’ei	p’ʌi	p’ipi	p’iju
p’ie	p’eu	p’ʌu	p’ipu	p’ija
p’io	p’eo	p’ʌe	p’ipa	p’uwi
p’iʌ	p’eʌ	p’ʌo	p’upi	p’uwa
p’ia	p’ea	p’ʌa	p’upu	
p’ui	p’oi	p’ai	p’upa	
p’ue	p’ou	p’au	p’api	
p’uo	p’oe	p’ae	p’apu	
p’uʌ	p’oʌ	p’ao	p’apa	
p’ua	p’oa	p’aʌ		

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