

Position and Height Asymmetries in Hiatus Resolution: A case study of Korean VV sequences

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Introduction

Typological patterns in synchronic data, for example, the question of why pattern A is more frequent than B across languages, have been one of the most important issues in linguistics, in particular in phonology. Ohala (1993) seeks the answer in human articulatory and/or auditory mechanisms. If a phonetic ‘perturbation’ is not corrected properly in perception, a hypo-correction could occur and it could result in a sound change. In this model, typological patterns are assumed to reflect the very variation in ordinary speech. Two crosslinguistic asymmetries in hiatus resolution are the main concerns in this paper. Casali (1996) and Rosenthal (1997) present positional and height asymmetries. They take another approach to the typological patterns in that they suggest universal constraints and rankings to account for the asymmetries in the framework of Optimality Theory (Prince and Smolensky 1993). Crosslinguistically, hiatus resolution such as vowel deletion or gliding is more likely to occur in V_1 and high vowels than in V_2 and non-high vowels. If these patterns result from human articulatory and auditory mechanisms as Ohala (1993) argues, it would be expected that the production of vowel sequences will show a pattern of phonetic variation, which is similar to the phonological processes. As the first step, a set of acoustic data on Korean hiatus is presented in this paper. The results will show that V_1 in hiatus is consistently shorter than V_2 , which corresponds to the positional asymmetry in Casali (1996). As for the height asymmetry, it will be reported that high vowels are more reduced in fast speech, compared to their durations in slow speech. In the next section, after presenting the typological asymmetries, the hypotheses will be presented with previous studies which provided the phonetic basis for the hypotheses. In section 2, the methods and results of a production experiment on Korean hiatus will be presented. Then, in section 3, the results will be discussed, focusing on what should be done in the future.

1 Previous Research

1.1 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 results in a conclusion 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_1 elision implies V_2 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 morphologically driven. To account for his finding, Casali proposes the universal constraint rankings in (1).

- (1) Universal rankings about hiatus resolution (Casali 1996: 31, 137)
 - a. $\text{PARSE(F)}-[w] \gg \text{PARSE(F)}$ (MAXWI \gg MAX in Casali 1997)
 - b. $\text{PARSE(F)}\text{-lex} \gg \text{PARSE(F)}$ (MAXLEX \gg MAX in Casali 1997)

The ranking in (1b) accounts for morphologically-determined elision (e.g., V_2 elision) and (1a) for the prevalence of V_1 elision, when hiatus takes place due to combination of morphemes.

Rosenthal (1997) presents additional typological findings on hiatus, which are given in (2). The focus was on the distribution of surface results of underlyingly prevocalic vowels (or V_1 s) such as deletion, glide formation, and epenthesis. (2a) and (2c) imply that if a prevocalic vowel is weakened,¹ high vowels should be the first.

- (2) Generalizations on the relation between distribution and vowel height (Rosenthal 1997: 140)
 - a. If a high vowel has a distribution (other than glide formation), other vowels have the same distribution.
 - b. Languages exhibit at most two outcomes of prevocalic vowels.
 - c. If mid vowels have nonmoraic counterparts, so must high vowels.

The two typological studies above can be generalized as two asymmetries in hiatus resolution, which are presented in (3).

- (3) 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 vowels.

¹ In this paper, ‘vowel weakening’ is defined as ‘losing nucleus status in syllabic structure’.

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It is not the case that weakening of high V₁ takes place only next to a morphological boundary. In language change, glide-formation of V₁ is very common even within morphemes, in particular when V₁ is high (Millar 2007: 80). Chitoran and Hualde (2007) found that the diphthongization of *iV* sequences 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 V₂ is not an initial segment of any morpheme or word as Casali proposes. 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.

1.2 Hiatus Resolution in Korean

Basically, Korean speakers use different strategies depending on the categories of words. Glide formation, glide insertion, and deletion (in particular, /u/, irrespective of its position) are applied in verbal suffixation and conjugation. In nouns, glide formation (underlined), deletion (**bold**), and coalescence (*italic*) are optionally adopted, as shown in table (4).²

- (4) 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	u	u	e	o	Λ	a
i			iu~ <u>ju</u>	ie~ <u>je</u>	io~ <u>jo</u>	iΛ~ <u>jΛ</u>	ia~ <u>ja</u>
u							
u	ui~ <u>wi</u>			ue~ <u>we</u>		uΛ~ <u>wΛ</u>	ua~ <u>wa</u>
e		eu~ e					
o	oi~ <i>we</i>	ou~ o					
Λ	Λi~ <i>e</i>	Λu~ Λ					
a	ai~ <i>e</i>	au~ a					

It seems that sonority (high V vs. non-high V), rather than position (V₁ vs. V₂), plays a crucial role in hiatus resolution in Korean. The higher the sonority is, the more likely the vowel is to be retained. For example, /u/ is deleted irrespective of its position in verbal suffixation and conjugation. However, Korean data do show some cases where V₂ looks weaker than V₁. /i+u/ and /e+Λ/ can be realized as [i] and [e] even though V₂ does not have lower sonority than V₁ (e.g.,

² 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.

[tɕ^{hiu}]~[tɕ^{hi}] ‘to put in order’ and [pɛλra]~[pɛra] ‘cut!’). This might be accounted for by the ranking in (1b), PARSE(F)-lex >> PARSE(F) since the first vowels in the examples belong to a root or stem. The Korean patterns have been assumed to be the result of phonological processes, rather than the result of automatic articulatory processes. While Kim (2000) employs different constraint rankings to explain speech 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 Rosenthal (1997) in that they view hiatus resolution as involving ‘phonological’ processes. Whether phonological processes or not, I assume that the aforementioned typological patterns are phonetically grounded, since some hiatus resolutions occur irrespective of morphological environments and they are sensitive to speech rate. Additionally, there is a case where hiatus resolution seems to be not a phonological process but a phonetic process. Van Heuven and Hoos (1991) 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. I speculate that phonetic details of hiatus will provide phonetic clues to the source of the typological patterns because such details should be the starting point of any kind of sound change leading to phonological hiatus resolution (Hyman 1977 and Ohala 1993). Also on the basis of the typological patterns in Casali (1996 and 1997) and Rosenthal (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

Hypothesis I : In fast speech, the steady state of V₁ will be reduced more than that of V₂.

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 (3) involves ‘shortening’ of its duration (note that gliding occurred in Romance languages when a prevocalic *i* was not lengthened). So Hypotheses I & II are related directly to the position & height asymmetries in (3). In the next section, we review relevant literature on vowels in sequences as supporting evidence for the hypotheses.

1.3 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 realiza-

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tions 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. Second, the formant properties of diphthongs were also revealed to be influenced by speech rate. In general, the faster the speech, the shorter the distance between onset and offset in the vowel space (for F1 and F2). It was concluded that the two crucial features of diphthongs are onset frequency and second-formant rate 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. As for 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. In sum, Gay revealed the most crucial part of English diphthongs (i.e., glide or transition) by comparing different speech rates and confirmed it by perception experiments. 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 1.1. 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 and that diachronically gliding results from ‘shortening’ of vowels. 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 1.2, 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.

2 Experiment

2.1 Methods

The materials for acoustic analysis were bisyllabic words containing VV sequences. Out of 7 monophthongs in Modern Korean (/i/, /u/, /ɯ/, /e/, /o/, /ʌ/, and /a/), 6 vowels excluding /u/ were adopted for both V_1 and V_2 .³ Combined with word-initial /pʰ/, the vowels produced 30 target nonce words ($pʰV_1V_2$, 6 vowels for $V_1 \times 5$ vowels, excluding the same vowel as V_1 , for V_2). Nine $pʰV_1pV_2$ (/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 CVCV sequences.⁴ To compare VV sequences with and without a glide, Four $pʰV_1GV_2$ (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 fillers⁵) was presented in written form, embedded in a sentence con-

³ The high back unrounded vowel /u/ was excluded because 1) /u/ 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 [u] at the phonetic level (Lee 1996), 2) /ui/ 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.

⁴ Labial stops were selected for the stimuli following Beddor et al (2002). The initial consonant was tense ($pʰ$), which have the shortest VOT period (Lee 1996) and the medial consonant was lax (p) because tense and aspirated consonants shorten the preceding vowel (Choi and Jun 1998).

⁵ 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.

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text, “*Mansuka _____-num wekukarako malhet’a.*” (“Mansu said _____ is a foreign word.”)

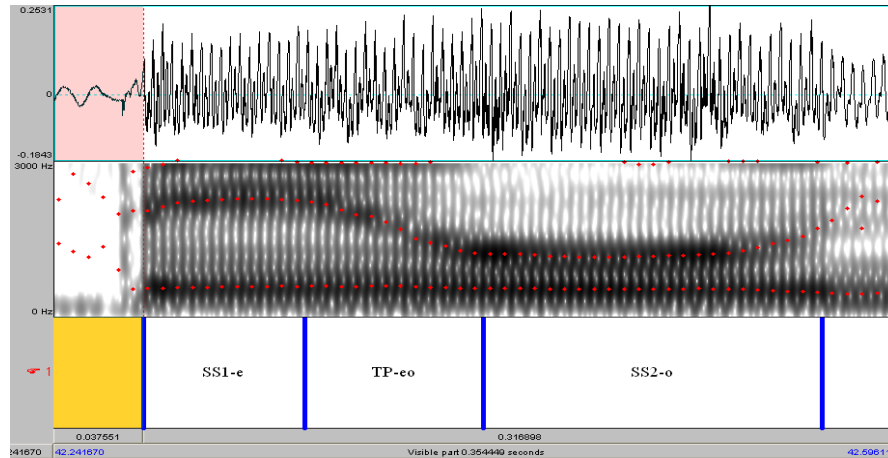
Six native speakers of Korean (three female and three male) were recorded. All were born in Seoul, where standard Korean is spoken, and were Stony Brook University students or their wives at the time of recording. The range of age was 24 to 32 (average was 28) and their length of stay in the US was 6 months to 4 years. Subjects were paid for their participation.

Recording was done in a sound-attenuated room at Stony Brook University. 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 \times 2 rates \times 3 repetitions \times 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.⁶ 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 (7), where the onset and the offset of TP are relatively prominent.

⁶ 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.

(7) 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.⁷ 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 V_1V_2 sequences. During the segmentation, 15 tokens⁸ (0.97%) were excluded because their formant structure did not show any observable change and 3 tokens⁹ (0.19%) were discarded because the targeted vowels were not 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 will be referred to as ‘word duration’.¹⁰ The durational proportions were calculated on the basis of this word duration.

2.2 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 ($F(1,5)=34.07$, $P<0.003$). The ratios (fast to slow) ranged from 0.40 to 0.72 and the average was 0.57.

⁷ 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.

⁸ They include 7 of ‘pou’, 3 of ‘puo’, 2 of ‘pao’, 1 of ‘pola’ and 2 of ‘pei’.

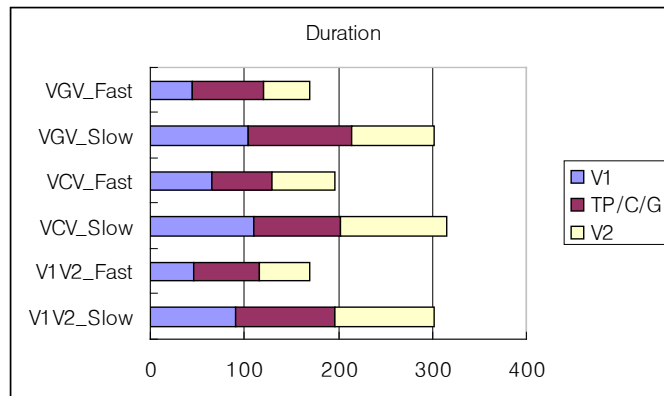
⁹ They include each of ‘pubu’, ‘poo’, and ‘paa’.

¹⁰ Word-initial /p’/ was excluded since there was no way to determine the beginning of the closure.

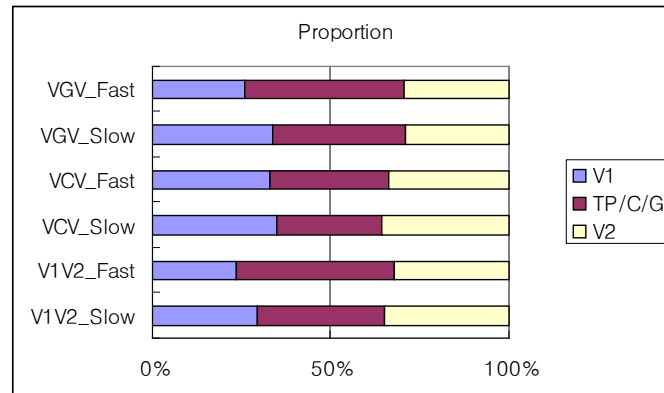
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Having shown a speech rate effect, we now consider whether the effect is stronger for V_1 (Hypothesis I) and whether high vowels are more affected than low vowels (Hypothesis II). The charts in (8) and (9) give segment and word durations in absolute (8) and proportionate (9) units. The data in (8) and (9) include the average durations of CV_1V_2 , $CVCV$, and $CVGV$ types for each speech rate. The chart in (8) shows that speech rate has an effect on the duration of each part as well as on the duration of the word. The chart in (9) gives an impression that $CVCV$ is fairly well-balanced while CV_1V_2 is slightly inclined to the left.

(8) Duration of V_1 , TP/C/G, and V_2 for three word types at two speech rates



(9) Proportion of V_1 , TP/C/G, and V_2 for three word types at two speech rates



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 proportions¹¹ with factors such as position and rate, for each word type. 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 ($F(1,5)=12.90$,

¹¹ 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 and Segerup 2000).

$P < 0.02$ for durations and $F(1,5) = 10.70$, $P < 0.03$ 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 SS₁ and 34.7% (3.75) → 32.1% (2.39) for SS₂). However, there was no interaction between rate and position ($F(1,5) = 1.52$, $P = 0.27$), even though the direction was consistent with Hypothesis I. This means that SS₁ is shorter than SS₂ but it is not reduced in duration significantly more than SS at fast rates. It seems that the duration asymmetry is unique to CV₁V₂ words. In CVCV words, proportions as well as durations were not different depending on the position of the vowel ($F(1,5) = 0.55$, $P = 0.49$ for durations and $F(1,5) = 0.35$, $P = 0.58$ for proportions). Speech rate made a significant difference in proportion ($F(1,5) = 21.42$, $P < 0.01$). 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 ($F(1,5) = 1.81$, $P = 0.24$ for durations and $F(1,5) = 0.04$, $P = 0.86$ for proportions), but there was a significant interaction between rate and position ($F(1,5) = 8.04$, $P < 0.04$). V₁ was longer than V₂ in slow speech but shorter in fast speech. In statistics, Hypothesis I was not confirmed. However, it was found that V₁ is shorter than V₂, which was not found in other types of words.

- (10) The durations and the fast/slow ratios of SS₁ and SS₂ 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

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 CV₁V₂ words. SS₁ was the shortest when V₁ 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 (10) make clear the reason for this interaction. The reduction of high vowel duration/proportion is bigger in SS₂ than in SS₁.

3 Discussion and Remaining Issues

This study began from typological asymmetries in both synchronic and diachronic hiatus resolution. The question was why V_1 tends to delete or glide more than V_2 , such that, for example, a sequence like /ia/ is much more likely to produce [ja] or [a] than would /ai/. Our acoustic analysis of Korean hiatus suggests some answers. First, the tendency for [i] to glide or to be lost may derive from the fact that the duration of V_1 is consistently shorter than V_2 , irrespective of speech rate, and the duration of a high vowel was reduced more than that of a non-high vowel, in fast speech. From the viewpoint of articulation, it seems likely that both effects 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. And the height asymmetry seems, ultimately, due to the intrinsic disparity between high and non-high 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 followup 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 .¹² 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 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

¹² Hyman (1977) 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.”

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 ₁ V ₂			CVCV	CVGV
p'iu	p'ei	p'li	p'ipi	p'iju
p'ie	p'eu	p'lu	p'ipu	p'ija
p'io	p'eo	p'le	p'ipa	p'uwi
p'ia	p'ea	p'lo	p'upi	p'uwa
p'ia	p'ea	p'la	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'ua	p'oa	p'ao	p'apa	
p'ua	p'oa	p'aal		

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