A Phonetic Account of the Current Inventory and Ongoing Changes of Korean Diphthongs*

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Kang, Hyeon-Seok. (2003). A phonetic account of the current inventory and ongoing changes of Korean diphthongs. *Language Research* 39(4), 809-838.

This research attempts to explain the current inventory and ongoing monophthongizing changes of Korean diphthongs on the basis of Ohala's (1992; 1993) phonetic explanation models of sound change and restrictions on sound sequences. This paper claims that in the history of Korean, perceptual factors have played an important role in the selection and shaping of diphthongs. To support this argument, perceptual distances between the component segments of all the combinationally possible diphthongal sequences of Korean are calculated. It is shown that the seven least acoustically-modulated and perceptually-salient diphthongal sequences are either nonexistent in the diphthongal inventory or presently undergoing monophthongization in Korean. This paper also shows that the phonetic, perceptual account of diphthongal cooccurrence restrictions in Korean is more effective and principled than the OCP-based phonological account.

Key words: sound change, diphthongs, monophthongization, perceptual factors, cooccurrence restrictions, maximal (sufficient) difference

1. Introduction

In the history of the Korean language, there have been some drastic changes in the inventory of diphthongs.[1] Some diphthongs have vanished;

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* The present research was conducted by the research fund of Dankook University in 2002.

1) (Seoul) Korean has nine 'glide+vowel' sequences and one 'vowel+vowel' sequence (See Figure 2 in Section 2). The two vowels in the 'vowel+vowel' sequence, undoubtedly belong to the same (syllable) nucleus. It is phonologically controversial, however, whether the glide in 'glide+vowel' sequences belongs to the nucleus of the syllable with the following vowel or to the syllable onset. It is not critical for this research whether it is assumed that the glide belongs to the nucleus (H. Y. Kim, 1990) or to the onset (Y. S. Lee, 1993). I will use both terms 'diphthongs' and 'diphthongal sequences' in this work. The former, coming from the assumption that glide and vowel forms a nucleus, has been traditionally used in Korean linguistics to refer to the 'glide+vowel' sequences. The latter 'diphthongal sequences' is more theory neutral than the former.

some came into being; and some have monophthongized. The status of the current Korean diphthongal system is like its past: It still shows interesting variations and ongoing changes, while not permitting some diphthongal sequences at all.

The present work will attempt to present a phonetic explanation of the current inventory of Korean diphthongs, which is the result of diachronic changes which have happened, and also of the phonological changes presently going on. The phonetic model adopted in this work is Ohala's (1981, 1993) perception model of sound change. This paper will attempt to show that Ohala's phonetic model of sound change and restrictions on sound sequences can clearly provide an efficient and principled explanation of the present inventory of and ongoing changes in (Seoul) Korean diphthongs.

Since diphthongs are sound sequences, some phonologists have relied on the formulation of the OCP(Obligatory Contour Principle)-based constraints in their attempt to explain restrictions on the combination of vocoids (i.e., vowels and glides) in diphthongal sequences. The present work will compare the proposed phonetic, perceptual account with possible OCP-based phonological accounts of the diphthongal changes and inventory of Korean, and will also attempt to show that the phonetic account based on Ohala's perception-based model can be a more effective and natural predictor of possible (and impossible) diphthongal sequences in this language than the phonological account.

This paper will proceed as follows. In Section 2, the diphthongal inventory of Korean will be introduced, and ongoing monophthongizing changes happening in the Korean diphthongal system will be discussed. In Section 3, Ohala's phonetic explanation model of sound changes and of constraints on sound sequences, which this work will heavily depend on for its phonetic account, will be introduced and described. A possible phonological account of the ongoing changes and constraints on diphthongal sequences in Korean will be proposed and criticized in Section 4, followed by the proposed phonetic account presented by the author in Section 5. A comparison of the phonetic and phonological accounts will be also made in this section. This article will end with conclusive remarks and statements about limitations of this work made in Section 6.

2. Background

In this section the present inventory of Korean diphthongs and changes in progress observed in the diphthongal system will be introduced and discussed. The Korean language examined in this work is, to be exact, the dialect of Korean spoken in Seoul and the surrounding *Gyeonggi* province, i.e., Seoul (or Standard) Korean. The prominent characteristic of this dialect in the diphthongal system is that it has been more resistant to changing processes, and thus the monophthongizing changes discussed below in subsection 2.2 started temporally later than other dialects of Korean.

2.1. The Inventory of Korean Diphthongs

The monophthongal system of Seoul Korean took its present form after the diphthongization of *ü* and *ö* to *wi* and *we* (Park, 1992), respectively, and the raising of *ε* to *e* (Hong, 1988). The vowel system of this dialect can be schematized as in Figure 1.

Figure 1. The Current Vowel System of Seoul Korean (Hong, 1988, p. 6).

i	ɨ	u
e	ə	o
	a	

Korean is similar to many other languages in that it has *w* and *y* as glides. However, these two glides cannot combine with every monophthong of Seoul Korean, which the following figure shows.

Figure 2. The Current Inventory of Korean Diphthongs

a. *w* diphthongs

wi	
we	wə
	wa

b. *y* diphthongs

		yu
ye	yə	yo
	ya	

c. isolated diphthong: ɨi

Only four vowels can combine with *w* and make diphthongs, while five form diphthongal sequences with the glide *y*. The diphthong *ɨi* is different from the other ones in that it has a considerably longer duration when fully phonetically realized. It is claimed that Korean had six or seven falling diphthongs (i.e., diphthongs whose latter component has less sonority than the former) and that these diphthongs disappeared one by one. The diphthong *ɨi* is regarded as the only remaining falling diphthong in Korean (Kim-Renaud, 1986).

2.2. Phonological Changes in Progress with the Korean Diphthongal System

Presently two monophthongization changes are claimed to be under way (Nam, 1984; Kang, 1998; 1999). These two are conditioned changes that have occurred earlier in certain phonological contexts than others.

2.2.1. Monophthongization of *ɨi*

The ongoing monophthongizing change of *ɨi* has been already observed and discussed by many previous works (Kim-Renaud, 1986; Nam, 1975). This diphthong shows somewhat variable monophthongization patterns across different dialects of Korean.[2] In the case of the Seoul dialect, *ɨi* is monophthongizing in the following way.

(1) 1. word-initial *ɨi* > *ɨ* (e.g., *ɨisim->ɨsim* 'doubt')
2. non-word-initial *ɨi* > *i*[3] (e.g., *hɨimang->himang* 'hope', *yuhɨi->yuhi* 'pastime', *yuɨi->yui* 'care')
3. possessive marker *ɨi* > *e* (e.g., *nəɨi son->nəe son* 'your hand')

In Kang (1999), recorded data from 63 Seoul Korean speakers were analyzed first based on percentages and further examined using Goldvarb 2, a multivariate statistical analysis software specially developed for sociolinguistic data. Only the results of the percentile analysis are given

2) In the Phyeongan dialect the diphthong has already changed to *i* or *u* after a consonant, and *i* or *ɨ* elsewhere (Y.B. Kim, 1992); in the Gyeongsang dialect the diphthong has changed to *i* with the exception of the possessive marker (Paek, 1990); in Gangweon and Chungcheong dialects (Toh, 1977), without a preceding consonant *ɨi* is usually produced as [i] in non-word-intial syllables and [ɨi] alternates with [ɨ] and [i] in word-intial position.

3) Non-word-initial position here includes two phonological contexts: post-consonantal position in the word-intial syllable and positions in a non-word-intial syllable.

below in Table 1. For the results and discussion of the multivariate analysis, refer to Kang (1999).

Table 1. Results of the Percentile Analysis of *ɨi*

1. post-consonantally (e.g., *hɨimang* 'hope', *yuhɨi* 'pastime')				
	'ɨi'	'i'	N	(dominant variant(s))
ingroup	2	98	43	
interview	1	99	101	
sentence reading	18	82	223	[i]
word reading	72	28	175	
2. non-post-consonantally a) word-initial position (e.g., *ɨica* 'chair')				
	'ɨi'	'ɨ'	N	
ingroup	44	56	16	
interview	54	46	106	
sentence reading	58	42	365	[ɨi]~[ɨ]
word reading	73	27	349	
b) non-word-initial position (e.g., *cuɨi* 'caution')				
	'ɨi'	'i'	N	
ingroup	0	100	29	
interview	5	95	261	
sentence reading	9	91	235	[i]
word reading	64	36	247	
3. as a possessive marker (e.g., na-ɨi 'my (*I*+Pos)')				
	'ɨi'	'e'	'N'	
ingroup	0	100	18	
interview	3	97	144	
sentence reading	26	73	834	[e]
word reading	28	71	336	

Four styles of speech data were elicited during the fieldwork for Kang (1998, 1999): ingroup speech, interview speech, sentence reading and word-list reading. (Ingroup speech refers to the data collected having a Seoul Korean speaker talk to his/her friends or relatives.) Because Korean is a language with a strong correspondence between orthographic symbols and actual pronunciations, and where read speech can be seriously affected by spelling pronunciations, occurrences of *ɨi* in read speech were not considered in data analysis. A close examination of the results of the analysis led to the following findings.

The diphthong *ɨi* seems to have (nearly) monophthongized to *i* in the post-consonantal (thus non-word-initial) phonological environment. The vowel *i* was the almost exclusive variant in this phonological context. 99 percent (142/144) of the tokens found in spontaneous speech (i.e. ingroup and interview speech) were realized as *i*. The same can be also said about non-post- consonantal *ɨi* in a non-word-intial syllable, where *ɨi* is the observed variant in 97 percent of the tokens found in this environment.

However, a tight competition is observed in word-initial position, where the variants *ɨi* and *ɨ* alternate with similar frequencies. Accordingly it can be claimed that *ɨi* has (almost) monophthongized to *i* in non-word-initial position, while the monophthongization of *ɨi* to *ɨ* is still an ongoing process. *ɨi* monophthongization is morphologically conditioned as well. The possessive marker *ɨi*, which always occurs in non-word-initial position, is nearly categorically realized as *e* in Seoul Korean.

2.2.2. Monophthongization of *ye*

The monophthongization of *ye* (to *e*) is also a change in progress in Seoul Korean. This diphthong, according to Y.S. Kim (1982), has already monopthongized in the Gyeongsang dialect and does not exist in this linguistic variety. The ongoing monophthongizing change of *ye* is sensitive to phonological contexts like *ɨi* monophthongization. The table below is part of the results of the Goldvarb 2 analysis of the tokens of (ye) observed in the data collected for Kang (1998). The listed constraint groups in the table were found to be statistically significant in the Goldvarb 2 analysis. The most important constraint on the variation involving *ye* monophthongization is the presence of the consonant preceding *y*. *ye* monophthongization, or the deletion of *y* before *e* occurs 90 percent of the time when there is a preceding consonant (e.g., *phyesu* 'waste water'). Secondly, whether *ye* occurs in word-initial position is another significant constraint when there is no preceding consonant; in non-word-initial positions (or syllables: e.g., *yuye* 'postponement') *ye* is monophthongized to *e* much more frequently than in word-initial position (e.g., *yesul* 'art'). As shown in the table, speech style and age are also meaningful constraints. Especially the fact that younger people have the tendency to produce the *e* variant more often than older speakers is a supporting piece of evidence that *ye* is monophthongizing to *e*. (In the table, the bigger the Goldvarb probability is, the chance of *y* being deleted is higher. For instance, the probability of *y* deletion after a preceding consonant is 0.668, while the probability is only 0.164 when there is no preceding consonant; the probability of *y* deletion in the word-initial syllable is merely 0.139, while that in the non-word-initial syllable is as big as 0.865.)

Table 2. Goldvarb Probabilities for Factors for *y* Deletion

Constraint groups	Constraints	Probabilities	Percentages[a]	N
Presence of preceding C	present	.668	90	2242
	Ø	.164	25	970
Word-internal position	initial	.139	55	1622
	noninitial	.865	85	1590
Speech Style	ingroup	.586	50	295
	interview	.560	56	502
	sentence R[b]	.536	74	1232
	word list R	.416	77	1183
Age	16-25	.615	76	1131
	26-45	.598	73	988
	46+	.301	61	1093

(NB: a. Percentages indicate percentages of *y* deletion.
b. R is an abbreviation of reading.)

In this section I have shown on the basis of previous work that *ɨi* and *ye* are currently undergoing monophthongization in Seoul Korean. In the next section, I will introduce (for the readers) Ohala's phonetic theory of sound change and his explanation model of constraints on sound sequences, which the present research will adopt for the explanation of the diphthongal changes that have been discussed in this section.

3. Ohala's Phonetic Explanation of Sound Change

Most historical linguists, following the Neogrammarians, define sound change as change in sounds that is conditioned or motivated by 'phonetic' factors. Researchers have proposed two types of phonetic motivation in sound change: the ease of articulation on the part of the speaker (Muller, 1864; Ladefoged, 1984) and perceptual constraints on the part of the listener (Sweet, 1888; Jonasson, 1971). Ohala places stress on the latter and takes the position that a majority of sound changes are perceptually motivated.

Ohala's phonetic account of sound change begins with the observation that there is an extreme degree of variability in speakers' production of sounds; the production of the 'same' sound is different not only from person to person but also in different phonetic contexts and in different speech rates and styles. The reason why each variation does not lead to 'sound change' is that the listener can normalize phonetic variations depending on the recognition of the phonetic environment where the sequence is produced and reconstruct the intended sound sequence. That is, the listener 'corrects' the distortions in the intended sound sequence and reconstructs the intended sequence based on his/her unconscious phonetic knowledge of the language.

There are, however, cases where the listener fails to 'correct' the distortions. Ohala suggests that a mini-sound change occurs in these cases. Three different types of mini-sound change are suggested. The first type is single confusion about the sound itself, which occurs when similar acoustic-auditory cues of articulatorily distinct sounds confuse the listener. One classic example of this type is observed in the development of Classical Greek from Proto-Indo European, where labial or labialized velar consonants change to labial stops (Meillet, 1967), e.g., *ekwo:s > hippos 'horse', *gwiwos > bios 'life'.

The second type of mini-change, referred to by Ohala as 'hypo-correction', occurs when the listener fails to normalize or correct for perturbations caused by the phonetic environment of the sound. According to Ohala, there can be two different situations of hypo-correction. The first is the situation when the listener does not have enough latent phonetic knowledge or linguistic experience of the language, as in the case of young children in the process of acquiring their language. The second situation arises when the listener, for some reason, fails to perceive the phonetic environment which causes or conditions perturbations in the intended signal. The reasons for failing to perceive the conditioning environment may be some lack of salience in the environment sound itself — as when oral or nasal stops are not released (thus not revealing the enough acoustic cues of stops) or when the conditioning sound is far away from the conditioned (affected) segment. One example of hypo-correction given by Ohala (1993) is the development of French nasal vowels from the 'vowel + nasal' sequence when nasal consonants are attenuated or totally eliminated. Ohala (1991) suggests that French nasal vowels arose because listeners failed to hear the nasal consonant and attributed the perturbations by the nasal to the vowel itself.

The third type of mini-change occurs when the listener corrects for imagined distortions which s/he thinks were conditioned by a certain phonetic environment. Ohala refers to this situation as 'hyper-correction' and claims that when the listener-turned speaker produces the sound sequence as s/he has erroneously reconstructed, this type of mini-change occurs. One such example is observed in a change from Pre-Shona to Shona (Mkanganwi, 1972).

(2) Pre-Shona Shona

*-bwa	> -bɣa	'dog'
*kumwa	> kumɣa	'to drink'

Ohala interprets this change, a change from a labio-velar /w/ to a velar (fricative) /ɣ/ after a labial, as follows. When the listener hears *w*, it gives cues of both a labial and a velar. Listeners, however, ascribe the labial portion of *w* cues to the preceding bilabial consonant and factor it out (hyper-correction). The velar portion of *w* cues, on the other hand, is not ascribable to any other adjacent sound and becomes the basis of reconstructing *w* as ɣ.

To sum up, Ohala claims that the following four outcomes occur when the listener receives the speaker's variable, often distorted, phonetic productions.

(3) 1. Correction
  2. Confusion of acoustically similar sounds
  3. Hypo-correction
  4. Hyper-correction

He suggests that among these the last three outcomes can lead to sound changes. He opposes the claim by some historical linguists that while assimilatory changes are natural, dissimilatory changes are not, a claim which presumably comes from the premise that ease of articulation or the principle of the least articulatory effort is the primary motivation of linguistic change. According to Ohala's view of sound change, i.e., the view that sound change is primarily motivated by perceptual factors, dissimilatory changes are at least as equally natural as assimilatory ones.

The scope of Ohala's phonetic account of sound change is not limited to changes in segments, but includes changes in sound sequences. Ohala

(1980, 1992) claims based on data from numerous languages that sound sequences which are observed often and shared by many languages are those that have sufficient perceptual difference among the components of sound sequences. In other words, maximum or sufficient perceptual distance between the components of sound sequences is important to languages' selection of sound sequences in general and durability of those sequences.

The fact that some sound sequences are prohibited or rarely observed in the world's languages is, according to Ohala, due to those sequences' lack of sufficient internal perceptual distinction and such sound sequences are apt to be non-existent from the beginning or to be lost even if those sequences were present at certain historical points of languages.

There have been studies (Wright, 1986; Kawasaki, 1986; Kawasaki-Fukumori, 1992; Lindblom, 1986, 1990) which support the main claim of Ohala's model of sound change, the claim that perceptual factors play an important role in sound change. Some of these studies are concerned with phonetic influence on sound change and others are on phonological universals in general (especially universal constraints on types of vowel systems and sound sequences). Among these, the most interesting and relevant to the present study are Lindblom (1986) and Kawasaki-Fukumori (1992).

Lindblom (1986) finds that vowel systems derived from the criterion that they have been largely shaped by the principle of 'sufficient perceptual contrast' closely match actual vowel systems of languages. Kawasaki-Fukumori (1992) calculates perceptual distance between segments of some selected sound sequences and finds that universally rare sound sequences have little or a small acoustic/auditory distance between the component segments. These researchers' works suggest that 'maximum/sufficient perceptual contrast' is an important causer or generator of sound change and of constraints on sound sequences in general. The researchers' findings can be taken to imply that acoustic/auditory factors play a major role in the diachronic selection of speech sounds and sound sequences.

I have discussed Ohala's phonetic model of sound change, his explanation of restrictions on sound sequences, and his emphasis on perceptual motivations of sound change in this section. In the following section, a possible phonological account of the present inventory of Korean diphthongs and of Korean diphthongal cooccurrence restrictions will be discussed as an alternative to the phonetic, perceptual account that will be proposed in Section 5.

4. A Possible Phonological Explanation and its Effectiveness

It was observed earlier that currently the diphthongs *ɨi* and *ye* are going through monophthongization in Korean. These two might be called 'unstable diphthongs', since it is possible that they might be lost in the inventory of Seoul Korean diphthongs at some future point in the long run. For the readers' reference, the diphthongs, unstable diphthongs, and prohibited diphthongal sequences of the present-day Seoul dialect are given in Figure 3.

Figure 3. The Diphthongs of Seoul Korean, the Gaps, and the Unstable Sequences

a. *w* diphthongs			b. *y* diphthongs		
wi	*wɨ	*wu	*yi	*yɨ	yu
we	wə	*wo	(*)ye	yə	yo
	wa			ya	

c. isolated diphthong: (*)ɨi

(NB: Gaps and unstable sequences are indicated by an asterisk and an asterisk inside parentheses, respectively.)

Traditionally phonologists have attempted to explain constraints on sound sequences relying on the Obligatory Contour Principle, which was defined by McCarthy (1986) as "at the melodic level, adjacent identical elements are prohibited." Yip (1988) claims that the OCP can function not only as a synchronic rule trigger but also as a trigger of a diachronic process. A similar approach was taken by Sohn (1991, pp. 200-201) to account for constraints on diphthongal sequences, **wu*, **wo*, and **yi*, and propose the following OCP constraints in Korean based on Clements (1985) and Sagey's (1986) feature models and also on the assumption that the glide and the following vowel form a nucleus (N) of the syllable:

Figure 4. Sohn's (1991) Proposed OCP Constraints in Korean

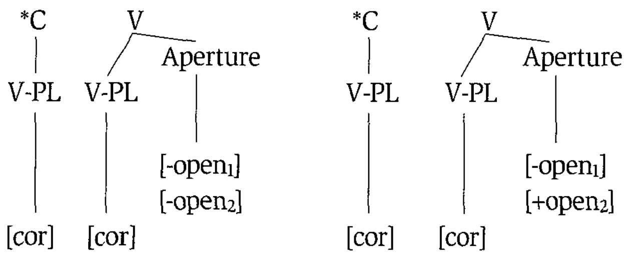
a. **wu*, **wo* (*[Labial Labial]) b. **yi* (*[[-back] [-back]]

I will reformulate below the constraints given in Figure 4 on the basis of Clements and Hume's (1995) more recent theory, i.e. the unified features model, which adopts the same set of place features for both consonants and vocoids. The reason why this model is used in this research is that in Korean the palaltal glide *y* has cooccurrence restrictions both with the preceding consonant and the following vowel. The palatal glide can neither precede the front vowel *i* (**yi*) nor follow the coronal consonant (**ty*, *t^h*y*, **t'y*, **sy*, **s'y*, **cy*, *c^h*y*, **c'y*) underlyingly in Korean. As shown previously, *y* also has occurrence restrictions with the following vowel *e* ((*)*ye*). Hence the adoption of the unified features model, which effectively explains interactions of glides with both the preceding consonant and the following vowel, can help provide more natural and simple phonological explanation in the case of Korean.

The constraints formulated in Figures (5a) and (5b) prohibit the sequences *yi* and *ye*, respectively. (Note that the feature [open] is arrayed on two tiers, tier 1 and tier 2. If [open] has a negative value on both tiers, it indicates a high vocoid; if [open] has a negative value on tier 1 but a positive value on tier 2, the vocoid is neither low nor high but mid.) While OCP(GV1: cor) is a 'hard' constraint, OCP(GV2: cor) is 'soft', historically newer, and 'strengthening'. The constraints formulated in Figures 5 and 6 should be understood as violable as proposed by Optimality Theory (OT: Prince & Smolensky, 1993).

Figure 5. Two Proposed OCP Constraints Against Adjacent Coronal Segments in Seoul Korean

a. OCP(GV1: cor) b. OCP(GV2: cor)



(NB: a. Similar yet not identical constraints to OCP(GV1: cor) are proposed in previous works such as Sohn (1991).
b. The constraints are formulated based on features proposed in Clements and Hume (1995).

The OCP constraints proposed by Sohn (1991) shown in Figure (4a) can be reformulated as OCP(GV: lab) given in (6a), which prohibits the sequences of a labial glide and a vowel (i.e., **wu* and **wo*). The constraint given in Figure (6b) is the one that causes instability in *ɨi* and triggers its monophthongization in Korean. It is assumed that the two component segments of *ɨi* are linked to two separate moras, following the standard assumption held by phonologists (Schane, 1995; McCarthy, 1995; Rosenthall, 1994) that falling diphthongs are associated with two moras. The constraint prohibits the sequence of two high vowels in the same syllable (i.e., *ɨi)* in Korean. This constraint is "softer" than the constraints given in (5a) and (6a) but may be slightly "harder" than the one given in (5b) at least at the present time.

Through the formulation of the constraints given in Figures 5 and 6, it can be claimed that the three prohibited (i.e., **yi*, **wu*, and **wo*) and the two unstable (*ye* and *ɨi*) sequences have been given a phonological explanation. However, a phonological account along these lines faces one serious problem, when it tackles the prohibited sequences **wɨ* and **yɨ*. No simple and plausible explanation can be given to why these sequences are not allowed in Korean, because the two components of each diphthongal sequence do not share any place features that are not shared by sequences *yu* and *wi*, both of which are possible diphthongal sequences in the Korean language. (The central vowel *ɨ* is phonologically placeless in

Clements and Hume's model and thus the only feature shared by component segments of **wɨ* and **yɨ* are [-open$_1$, -open$_2$], i.e., [+hi], which is, without doubt, shared by *yu* and *wi*.)

Figure 6. Two OCP Constraints that can be Formulated for a Partial Explanation of Co-occurrence Restrictions on Diphthongal Sequences in Seoul Korean

a. OCP(GV: lab)

```
*C          V
|           |
V-PL        V-PL
|           |
[lab]       [lab]
```

b. OCP(VV: -open1,-open2)

```
*V              V
|               |
Aperture        Aperture
|               |
[-open1]        [-open1]
[-open2]        [-open2]
```

domain: syllable

5. A Phonetic Explanation

Ohala's perception-based account of segment sequential constraints, on the other hand, seems to provide a simpler and more principled explanation of why the sequences *wɨ*, *wu*, *wo*, *yi*, and *yɨ* are not allowed in this dialect, as well as of instability in *ye* and *ɨi*. First we need to consider what a diphthong is.

In phonetic terms, diphthongs are defined as vowel-like sequences that cannot be characterized by a single vocal tract shape or by a single formant pattern (Kent & Read, 1992; Laver, 1994). A diphthong is normally considered as consisting of two components: 'glide + vowel' or 'vowel + glide', but two vowels can also form a diphthong. The terms 'onglide' or 'onset' are used to refer to the first part of the diphthong and the terms 'offglide' or 'offset' to refer to the second part. Phoneticians also use the term 'nucleus' to indicate the more sonorous component of a diphthong, whether it is onset or offset. Usually when the onset is more sonorous than the offset, the diphthong is called a falling diphthong; it is called a rising diphthong in the opposite case.

There is one notable fact about the diphthongs observed in the world's languages: Languages seem to prefer a certain type of diphthongal sequences to others. According to Lindau, Norlin and Svantesson (1990), diphthongs occur in about one third of the world's languages. Diphthongs of the *ay*-type occur in 75 percent of these languages and the *aw*-type occur in about 65 percent of these. Estrom (1971) examined 83 languages with diphthongs and reports that languages prefer diphthongal sequences whose nucleus has greater sonority (or amplitude), i.e., languages favor low vowels over mid vowels, and mid vowels over high vowels as a nucleus of the diphthong. The summary of Estrom's findings can be seen in Table 3.

Table 3. Percentage of Languages for Which the Indicated Vowel is the Nucleus of a 'Nucleus + Glide' Sequence (N=83)

(Source: Ström, 1971 (quoted in Lindblom, 1986, p. 37))

a/ɑ	o/ɔ	e/ɛ	u	i
83%	34%	25%	18%	7%

A similar suggestion is made by Kawasaki (1982) based on her survey of diphthongs of languages. She (ibid., p. 28) states that "combinations of a low vowel and a high vowel are favored over other combinations of vowels", which finding is basically very close to that of Lindau et al. (1990). Another important point her survey reveals is that rising diphthongs also prefer the combination of 'low vocoid + high vocoid', though the sequence in their cases is not 'low vowel + high glide' but 'high glide + low vowel' (Kawasaki ibid., p. 28).

The findings of the above three studies point to the languages' preference of diphthongs whose onset and offset are maximally (or sufficiently) different in the acoustic-auditory domain. These survey studies also give support to rather impressionistic observations made by scholars (Stampe, 1972; Rosenthall, 1994) that languages favor diphthongal sequences with maximal differentiation in formant frequency and/or sonority (amplitude) between onglide and offglide.

I have suggested above that languages generally favor diphthongal sequences with maximal (or sufficient) internal distinction in component vocoids. Korean does not seem to be an exception in this regard. As shown above in Figure 3, the sequences **wu* and **yi* are not allowed in Korean. Ohala (1980, 1992) makes the claim that maximum or sufficient perceptual distance is crucial to languages' selection of not only diphthongal sequences but sound sequences in general. He (1992, p. 325) makes the suggestion that the following four acoustic parameters are the most relevant to the perception of sound sequences: spectral shape, amplitude, periodicity and fundamental frequency. Among these, spectral shape (which, for vowels, can be largely understood in terms of formant frequency) and amplitude are considered as relevant parameters in the perception of diphthongal sequences, because onglide and offglide of diphthongs, both vocoids, are not distinguished well in periodicity (i.e., voicing) and fundamental frequency (F0). The importance of formant frequency and amplitude in the languages' selection of diphthongs is clearly revealed by the results of the three studies of diphthongs discussed above. I will show below that the diphthongal sequences that are prohibited or undergoing monophthongization in Korean are those whose onset and offset are the least perceptually contrastive among the diphthongs of this language.

We will first consider formant frequency among the two acoustic parameters relevant to the perception of diphthongs. There is a general agreement among phoneticians that the first three formants are important in vowel perception, and also that especially F1 and F2 are the most significant in the perception of diphthongs as well as of monophthongs (Fox, 1983). F1 and F2 are, thus, examined in this work. The present study relies on Yang (1996) for the F1 and F2 frequency values. Given in Table 4 are the average F1 and F2 values of the monophthongs of Seoul Korean produced by ten male speakers.

As discussed early, Ohala's position was that perceptual rather than

Table 4. Average F1 and F2 Values of Seoul Korean Monophthongs Produced by 10 Male Speakers (Yang, 1996, p. 251)

Vowel	F1 (Hz)	F2 (Hz)
i	341	2219
e	490	1968
ɨ	405	1488
a	738	1372
ə	608	1121
u	369	981
o	453	945

acoustic factors play a more important role in sound changes and languages' selection of sound sequences, meaning that a perceptual rather than acoustic scale is more relevant to the current discussion. Accordingly, Hz values of F1 and F2 given in Table 4 have been converted to Mel values using the formula below:

(4) $P = (1000/\log_{10} 2)\,(\log_{10}(1 + f/1000))$ (Fant, 1973, p. 48)

In order to measure the difference in formant frequency between onset and offset of Korean diphthongs, the calculation of the standard Euclidian distance on the 'formant frequency' plane, i.e., F1 * F2 plane, was performed using the formula given as (5), where the 'glide' distance from onset (i) to offset (n), Din is defined as the Euclidian distance form the two coordinate points, (M1i, M2i) and (M1n, M2n), on the F1 * F2 plane. It should be noted that the formant values of *y* and *w* are very similar to *i* and *u*, respectively, because the shape of the vocal tract when *y* and *w* are produced are highly similar to that for the production of *i* and *u*, respectively (Kent and Read, 1992, p, 136). Since Korean has *y* diphthongs and *w* diphthongs as well as *ɨi*, the distance from both *i* and *u* will be calculated.

(5) $Din = \sqrt{(M1i - M1n)^2 + (M2i - M2n)^2}$
(NB: Din: glide distance from onset to offset of a diphthong;
M1 and M2: F1 and F2 values in Mel)

Table 5. Perceptual Distance of Each Vowel of Seoul Korean from *i* in Terms of 'Formant Frequency' (calculated based on the F1 and F2 Hz values given in Table 4)

Vowel	F1 (Mel)	F1-difference from *i*	F2 (Mel)	F2-difference from *i*	Euclidian distance from *i* in terms of formant frequency (Mel)
i	423	0	1687	0	0
e	575	152	1570	117	192
ɨ	491	68	1315	372	378
a	798	375	1246	441	579
ə	685	262	1085	602	657
u	453	30	986	701	702
o	539	116	960	727	736

Results of the calculations are given in the last column of Tables 5 and 6. Though onset and offset of diphthongs do not necessarily correspond exactly to a monophthong produced independently (Ladefoged, 1982), the tables show that *e* and *ɨ* are the perceptually closest to *i* on the F1 * F2 plane in 'formant frequency' (i.e., spectral shape), while and *o* and *ə* are the nearest to *u*.

Table 6. Perceptual Distance of Each Vowel of Seoul Korean from *u* in Terms of 'Formant Frequency' (calculated based on the F1 and F2 Hz values given in Table 4)

Vowel	F1 (Mel)	F1-difference from *u*	F2 (Mel)	F2-difference from *u*	Euclidian distance from *u* in terms of formant frequency (Mel)
u	455	0	990	0	0
o	541	86	963	27	90
ɨ	492	37	1319	329	331
ə	688	233	1088	98	253
a	800	345	1250	260	432
i	425	30	1692	702	703
e	577	122	1575	585	598

We will go on to examine the difference between onset and offset of the Korean diphthongs in another acoustic parameter, 'amplitude'. There is a general agreement among phoneticians that the amplitude or intensity of vowels is highly correlated with the frequency value of F1 (for instance, Lindblom (1979, p. 161) suggests that "vowel intensity is governed mainly by the frequency of the first formant."), which also shows significant correlations with vowel height and mouth opening (Kent & Read. 1992, p. 92). This means that amplitude of vowels can be roughly approximated by the frequency value of F1, and that the difference in amplitude between onset and offset of diphthongs can be approximated by the difference in the F1 values of the two. On the basis of this rationale, the present study uses the absolute difference in (Mel transformed) F1 values between onset and offset for the approximation of the amplitude distance between the component segments of diphthongs.

In the second and third columns of Table 7, the F1 values of Seoul Korean monophthongs and their (respective) differences from the F1 value of the vowel *i* are provided. The difference in F1 values between *u* and each vowel of Seoul Korean is given in the last column of Table 8. Since again a perceptual rather than acoustic scale is relevant here, the Hz values have been converted to the Mel values using the formula given as (4). Results given in Table 7 suggest that *u* and *ɨ*, both high vowels, have the shortest amplitude distances from *i*, whereas it can be seen in Table 8 that vowels *i* and *ɨ* are the closest to, i.e., the least different from, *u* in terms of perceptual amplitude.

Table 7. Difference in F1 Values (Mel) Between *i* and Each Vowel of Seoul Korean as an Approximation of the Perceptual Amplitude Distance from *i*

Vowel	F1 (Mel)	F1-difference from *i* (Mel)
i	423	0
e	575	152
ɨ	491	68
a	798	375
ə	685	262
u	453	30
o	539	116

Table 8. Difference in F1 Values (Mel) Between *u* and Each Vowel of Seoul Korean as an Approximation of the Perceptual Amplitude Distance from *u*

Vowel	F1 (Mel)	F1-difference from *u* (Mel)
u	455	0
o	541	86
ɨ	492	37
ə	688	233
a	800	345
i	425	30
e	577	122

Following Ohala's suggestion that sound sequences are governed by the simultaneous effects of several factors (of which we are considering spectral shape and amplitude), we can combine the formant frequency and amplitude measures just discussed into a 'composite' perceptual distance measure. The 'composite' perceptual distance can be approximated by taking both amplitude distance, approximated by the difference in F1 values, and glide distance on the F1 * F2 plane into consideration.

It is not an easy question how to weight formant frequency and amplitude, the two acoustic parameters relevant in the perception of diphthongs. No established answer to this question is known to us. One reasonable and plausible method of calculating the composite distance is to obtain the average of the following two values giving an equal weight to the two — glide distance between the onset and the offset and amplitude distance between the onglide and the offglide approximated by the difference in F1 values. The underlying assumption of this method is that differences in formant frequency and amplitude (between the onset and the offset) play comparable roles in the perception of diphthongs. The rightmost columns of Tables 9 and 10 list the approximated perceptual distance of each of the combinationally possible *y* and *w* diphthongal sequences calculated in this method, respectively. The tables show that *yi*, *wu*, *wo*, *ye*, *wɨ*, *yɨ* and *ɨi* are the seven least perceptually distinguishable among the (logically) possible diphthongal sequences in Korean.

Table 9. Composite Perceptual Distance of Each of the '*y* + Vowel' Sequences Obtained by Averaging the Values of Glide Distance on the F1 * F2 Plane and Amplitude Distance as Approximated by the Differences in F1 Values

Diphthongal sequences	Perceptual distance in terms of formant frequency (Mel)	F1-difference (Mel)	Average difference (Mel)
*yi	0	0	0
*yɨ, ɨi	378	68	223
ye	192	152	172
ya	579	375	477
yə	657	262	460
yu	702	30	366
yo	736	116	426

Table 10. Composite Perceptual Distance of Each of the '*w* + Vowel' Sequences Obtained by Averaging the Values of Glide Distance on the F1 * F2 Plane and Amplitude Distance as Approximated by the Differences in F1 Values

Diphthongal sequences	Perceptual distance in terms of formant frequency (Mel)	F1-difference (Mel)	Average difference (Mel)
*wu	0	0	0
*wo	90	86	88
*wɨ	331	37	184
wə	253	233	243
wa	432	345	389
wi	703	30	367
we	598	122	360

Another possible method of calculating the composite perceptual distance is to weight the F1 difference heavier than the F2 difference and then approximate the perceptual difference between the onset and the offset. Lindblom (1979, 1986) suggests that languages exploit differences in F1 significantly more than differences in higher formants in the distinction of their vowels. He (1986, p. 22) observes "if vowel systems had developed security margins guaranteeing a certain amount of perceptual differentiation in communication under noisy conditions, they would be expected to exploit F1 (height or sonority) more than other formants...". Lindblom (1979) shows that the frequency of confusions in the identification of vowel pairs in Swedish and English can be chiefly determined by the first formant differences between vowel pairs, i.e., the smaller difference in F1 values there exists between a vowel pair, the more often the pair was confused with each other. On the basis of this observation, Lindblom makes the proposal to weight F1 significantly heavier than higher formants in the prediction of possible vowel systems of the world's languages, while not attempting to provide a definite answer to the question of how much more weight should be assigned to the F1 difference.

In our case, one plausible weighting is to give the F1 difference twice the weight of the F2 difference because the former is relevant to both glide distance on the F1 * F2 plane and amplitude distance (between the onset and the offset), while the latter concerns only the distance in

Table 11. Composite Perceptual Distances of the 'y + Vowel' Sequences Obtained by Giving Twice as Heavy Weight to the F1 Difference as to the F2 Difference

Diphthongal sequences	2 * Perceptual F1 difference (Mel)	Perceptual F2 difference (Mel)	Perceptual distance from i (Mel)
*yi	0	0	0
*yɨ, ɨi	136	372	396
ye	304	117	326
ya	750	441	870
yə	524	602	798
yu	60	701	704
yo	232	727	763

(6) $Din(composite) = \sqrt{(2*(M1i - M1n))^2 + (M2i - M2n)^2}$

Table 12. Composite Perceptual Distance of the 'w + Vowel' Sequences Obtained by Giving Twice as Heavy Weight to the F1 Difference as to the F2 Difference

Diphthongal sequences	2 * Perceptual F1 difference (Mel)	Perceptual F2 difference (Mel)	Perceptual distance from i (Mel)
*wu	0	0	0
*wo	172	27	174
*wɨ	74	329	337
wə	466	98	476
wa	690	260	737
wi	60	702	705
we	244	585	634

formant frequency. The standard Euclidian distance can, then, be calculated using the formula given as (6). The final columns of Tables 11 and 12 list the perceptual distance between onset and offset of each of the combinationally possible diphthongal sequences of Korean calculated using this method.

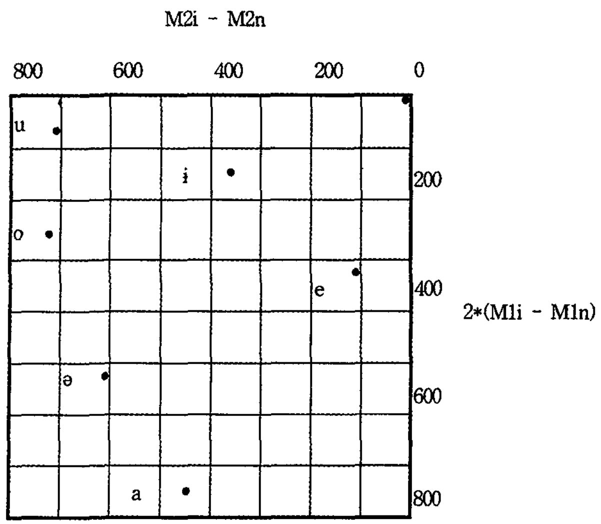
Very comparable results are produced by the two proposed methods of calculating the composite perceptual distance. Both identify *yi, wu, wo, ye, wɨ, yɨ* and *ɨi* as the seven diphthongal sequences with the shortest perceptual distance between onset and offset. (This means that both the two indicate that the seven diphthongs are the least perceptually salient and thus the most perceptually unstable (Refer to the hierarchy of perceptual instability made based on Tables 9-12 given as (7))). The two methods also identify *ya* and *wa* as the most optimal among *y* and *w* diphthongs, respectively.

(7) The Perceptual Instability Hierarchy based on Ohala's (1992) model

*yi,*wu<*wo<ye<*wɨ<*yɨ, ɨi<wə<we<yu<wi<wa<yo<yə<ya

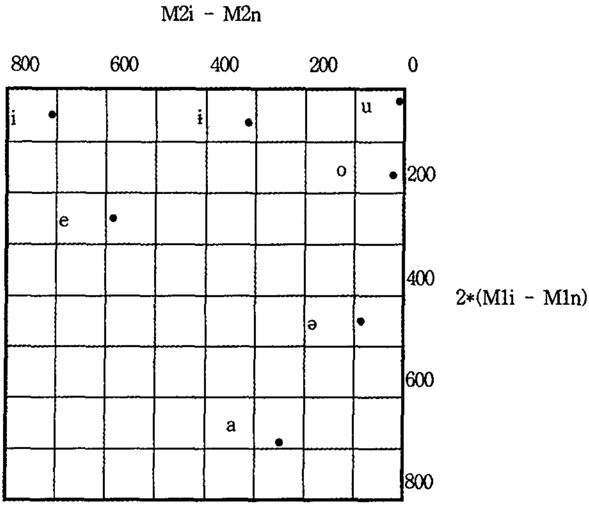
The sequences *yi, wu, wo, wɨ,* and *yɨ* are not allowed in Korean; *ɨi* and *ye* are, as discussed earlier, currently going through monophthongization. This means that the least perceptually optimal diphthongal sequences are either prohibited or undergoing phonological change in this language. The perceptual distance between onset and offset of the (logically) possible '*y* + vowel' and '*w* + vowel' sequences are shown in Figures 7 and 8, respectively, where the weighted differences in F1 and F2 of each vowel from *i* and *u* (the values are from Tables 11 and 12) are located on the perceptual distance plane. Figure 7 shows that vowels *e* and *ɨ* are located significantly closer to *i* than any other vowel of Korean, while it can be seen in Figure 8 that *o* and *ɨ* have a clearly shorter perceptual distance from *u* than any other vowel.

Figure 7. Seoul Korean Vowels on the Plane of Perceptual Distance from *i* NB: The (x,y) Mel values for each vowel are from Table 11



In this section, I have presented a phonetic account of the constraints on diphthongal sequences and diphthongal changes in Seoul Korean along Ohala's lines. The presented phonetic account seems to have some advantages over the OCP-based phonological explanations given in Section 4. These advantages will be briefly discussed below.

Figure 8. Seoul Korean Vowels on the Plane of Perceptual Distance from *u* NB: The (x,y) Mel values for each vowel are from Table 12



First, the phonetic account provides an explanation of all the cooccurrence restrictions in the diphthongal system of Seoul Korean, which include sequences not allowed and those becoming increasingly more prohibited. The phonological account, on the other hand, does not seem very effective: It can provide cooccurrence constraints on the sequences *yi, wu, wo, ye,* and *ɨi* but not on *yɨ* and *wɨ*, the components of which do not share any place features that are not shared by *yu* and *wi*, two possible diphthongal sequences in Korean.

Secondly, the phonetic account seems to present a more simple and principled explanation than the OCP-based phonological account: The diphthongal sequences which are prohibited or currently showing instability in Seoul Korean are the seven least acoustically modulated diphthongal sequences in terms of spectral shape and amplitude, i.e., the seven diphthongal sequences with the least perceptual saliency. On the other hand, the phonological account needs to formulate four different OCP constraints to explain cooccurrence restrictions on five diphthongal sequences. In short, it can be claimed that though the phonetic account has its own limitations, the phonetic, perceptual explanation of the current inventory and ongoing changes of Korean diphthongs is more accurate, simple, and efficient than the OCP-based phonological explanation discussed in Section 4.[4)]

6. Conclusion

The present work has attempted to explain synchronic cooccurrence restrictions in the Korean diphthongal system on phonetic terms on the basis of Ohala's theory and tried to show that the phonetic, perceptual account of the cooccurrence restrictions can be more effective than the phonological account.

We, however, observe that in the history of Korean two factors other than the phonetic, perceptual one have also played a significant role in the shaping of the Korean diphthongal inventory. The first factor is changes in the monophthongal system, which tended to trigger changes in the diphthongal inventory. The addition of *wi* in the 20C, for instance, was a result of the diphthongization of *ü*.[5)] The loss of *yʌ* and *ʌy* in the 17C came from the loss of *ʌ* from the vowel inventory. The loss of *wɛ* and *yɛ* in the 20C, on the other hand, originates from the merging of *ɛ* and *e* (Hong, 1988). All these changes provide clear evidence that monophthongal changes in Korean have often caused changes in the diphthongal system of this language.

Linguists dealing with historical data have observed that at least some sound changes are triggered by the influence of phonological structure.

4) It should be admitted that the phonetic account presented does not provide answers to the questions such as why the Korean language, in the first place, had sequences like *ye* and *ɨi*, which are not very perceptually optimal or why *ɨi* is ahead of *ye* in monophthongization though the former is relatively more perceptually optimal than the latter (refer to the hierarchy of perceptual instability (7)). Past research in diachronic linguistics, however, has shown us that social, cognitive, or systemic factors as well as phonetic factors can also play a role in sound change. It also needs to be added that articulatory factors can also have an influence on the shaping of languages' diphthongal systems, though the current work emphasizes perceptual factors.

5) It is not clear, though, whether *wi* came exclusively from *ü* or there was another source in the formation of this diphthong.

Researchers (Gvozdanvić, 1985) have suggested that these so-called 'structurally-conditioned' changes are caused by a language-internal drive to preserve sufficient contrast and symmetry in phonological structure (see Hock, 1986, p. 159ff.).[6] We observe that this structural motivation was another factor that has contributed to diphthongal changes in Korean. The monophthongization of most Korean falling diphthongs was motivated by this structural factor; the loss of *əy* and *ay* and the subsequent loss of *oy* and *uy* from the diphthongal inventory (through their monophthongization to *e*, *ɛ*, *ö*, and *ü*, respectively) are conjectured to have been motivated by the need to redress the asymmetry in the Korean monophthongal system in the 18C as shown in Figure 9 (cf. Paek, 1990, p, 92).

Figure 9. The Monophthongal Systems of Seoul Korean Before and After the Monophthongization of *əy*, *ay*, *uy*, and *oy*

a. Before the changes (early 18C)			b. After the changes (late 19C)			
[-bk]	[+bk]		[-bk]		[+bk]	
i	ɨ	u	i	ü	ɨ	u
	ə	o	e	ö	ə	o
	a		ɛ		a	

This research, accordingly, does not claim that only the perceptual factor has been the decisive force in the changes and shaping of the Korean diphthongal system, though it suggests that it might be the most significant among the three factors. The following are additional pieces of evidence supporting my claim that a perceptual factor has played a major role in shaping the diphthongal inventory of Korean. First, this language never had *wu*, *wo*, and *wɨ*. It is also a majority opinion (Huh, 1965; B.H. Choi, 1985) that *yi* and *iy* were never part of the diphthongal system of this language. When a common property of these diphthongal sequences, i.e., small internal-acoustic modulations, is considered, the indication of these diachronic facts is that the above five diphthongal sequences have not been adopted by this language because of their lack of perceptual saliency

6) The most prominent and well-known examples of these structurally-motivated changes are chain shifts that have been observed in various languages including Korean.

or stability (cf. Tables 9-12). Even if it were the case that *yi* and *iy* had been present in this dialect at one time and were lost (as some scholars (S. H. Choi, 1977) claim), it is deemed that perceptual instability of these diphthongs must have played a major role in the (hypothetical) subsequent loss of the two.

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Received: Sep. 1, 2003
Revised version received: Nov. 1, 2003
Accepted: Nov. 3, 2003