KHALKHA MONGOLIAN VOWEL HARMONY:
AN OPTIMALITY THEORETIC ANALYSIS

Boer Fu
University of California, Los Angeles

ABSTRACT

This paper aims to account for Khalkha Mongolian vowel harmony with an Optimality Theoretic analysis. A brief description of the intricate rules of Mongolian ATR and rounding harmony is given as an introduction. Previous analyses of this phenomenon are then to be discussed, all of which fail to explain the transparency of [i] and opacity of [u] and [ʊ] with an integrated theory. At which point, an Optimality Theoretic analysis is needed to consistently predict the surface representations of Mongolian vowel harmony under the principles of Richness of the Base. A brief discussion on the significance of the transparent [i] is provided before fleshing out a comprehensive Optimality Theoretic analysis of Mongolian vowel harmony, with ranking of constraints explained.

1. INTRODUCTION

Mongolian is a Mongolic language with 5.2 million (Svantesson et al. 2005:141) native speakers in East Asia. As the official language of Mongolia, it is also spoken in some parts of China and Russia. Kalmyk (Western Mongolia), Khalkha (Ulaanbaatar), Shuluun Höh (Inner Mongolia), and Buriat (Russia) are major Mongolian dialects that are spoken today, all of which have vowel harmony of some degree. The focus of this paper is Khalkha (or Halh) Mongolian, the standard dialect in Mongolia, and its pharyngeal and rounding harmony.

Some of the data used in this study are words found in *The Phonology of Mongolian* written by Svantesson et al. (2005), with pronunciation confirmed by a native speaker, Gan Od Bayarbaatar. She was born in Ulaanbaatar, the capital city of Mongolia. Prior to moving to Los Angeles, California, she went to schools where classes were taught in Khalkha Mongolian. Additional data are elicited from Gan on several occasions, based on wordlists selected from two dictionaries — *A Modern Mongolian-English Dictionary* (Hangin et al. 1986) and *A Concise English-Mongolian Dictionary* (Hangin 1970).

Transcriptions used in this paper conform to the International Phonetic Alphabet (IPA), with some additional Cyrillic Mongolian alphabet for easy reference.

1.1 PHARYNGEAL HARMONY

Khalkha Mongolian has seven vowels in its inventory: [i], [e], [a], [u], [ʊ], [o], [ɔ], as shown in Figure 1.

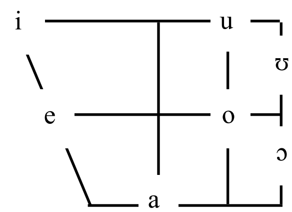

Figure 1

The seven vowels are divided into two harmony classes according to the presence or absence of the feature [pharyngeal], which involves the lowering of the pharynx (Svantesson et al. 2005:43). [ʊ], [a], and [ɔ] are pharyngeal vowels, whereas [i], [e], [a], and [u] are non-pharyngeal vowels. In any given word of Mongolian, only vowels from the same harmony class can appear alongside each other.

(1)	Mongolian IPA	Mongolian Cyrillic	English		Mongolian IPA	Mongolian Cyrillic	English
a	tiɮgur	дэлгүүр	‘shop’	c	cʊrɢa	зургаа	‘six’
b	ʃuuge	шүүгээ	‘cupboard’	d	xɔtʃʊɮ	хожуул	‘stump’

(1a-b) have only non-pharyngeal vowels, while (1c-d) have only pharyngeal vowels.

The high front vowel [i] is special in that it can co-exist with pharyngeal vowels in a word, but when it is seated in a monosyllabic stem, it dictates that the suffix vowel has to be non-pharyngeal. It might also be interesting to note that when [i] is part of a diphthong, it has no say in the harmony class of the word. Even when it is part of a diphthong in the initial syllable, pharyngeal vowel harmony passes over its head unto the next syllable with no hindrance.

(2)	Mongolian IPA	Mongolian Cyrillic	English		Mongolian IPA	Mongolian Cyrillic	English
a	pɔitɔ	бойдоо	'be bent'	c	xʊiɮa	хуйлаа	'table'
b	xairʊ	хайруу	'thin'	d	guimxi	гүймхий	'gap'

The invisibility of [i] to pharyngeal vowel harmony goes beyond the realm of diphthongs. In a trisyllabic word where the second syllable is [i], pharyngeal harmony passes over its head as well. This is called the transparency of [i].

(3)	Mongolian IPA	Mongolian Cyrillic	English		Mongolian IPA	Mongolian Cyrillic	English
a	poor-ig-o	бөөрийгөө	'kidney-ACC-RFL'	c	xɔɔɮ-ig-ɔ	хоолыгоо	'food-ACC-RFL'
b	suuɮ-ig-e	сүүлий	'tail-ACC-RFL'	d	mʊʊr-ig-a	муурыгаа	'cat-ACC-RFL'

1.2 ROUNDING HARMONY

Mongolian also has a rounding harmony. Vowels in a given word agree on their value of the feature [round]. Rounding harmony is much less strictly applied than pharyngeal harmony, for only the open or non-high vowels [e], [a], [o], and [ɔ] participate.

(4)	Mongolian IPA	Mongolian Cyrillic	English		Mongolian IPA	Mongolian Cyrillic	English
a	peeɮi	бээлий	'glove'	d	jama	ямаа	'goat'
b	xooc	хөөцөө	'heat'	e	tɔɮɔ	долоо	'seven'
c	une	үнээ	'cow'	f	pʊʊxʲa	буухиа	'courier'

The first two rows of (4) display active rounding harmony. The last row, however, shows that high rounded vowels [u] and [ʊ] are not only immune to rounding harmony, but actually forbid the suffix vowel to be rounded. And when they assume word-medial position in a trisyllabic word, the roundness of the initial syllable do not pass through them to the final syllable, as seen in (5) below. This is a phenomenon that contrasts with the transparency of [i], and is branded as the opacity of U (as an archiphoneme).

(5)	Mongolian IPA	Mongolian Cyrillic	English		Mongolian IPA	Mongolian Cyrillic	English
a	og-uɮ-ɮe	өгүүллээ	‘to give-CAUS-DPST’	b	ɔr-ʊɮ-ɮa	оруулаа	‘to enter-CAUS-DPST’

Refer back to the example in (3), [i] is transparent to rounding harmony too. It not only fails to hinder the harmonization of [+round] feature, but also passes on the opacity of [u] and [ʊ] with high fidelity.

2. TRADITIONAL ANALYSIS

Previous literature on Mongolian tends to be more descriptive than analytical. Poppe (1970) classifies the vowels into front: [e], [o], [u], and back: [a], [ɔ] and [ʊ]. Diphthongs derive their classification from the vowel other than [i] or [e] (Poppe 1970), which is translatable to the concept of [i] transparency. Poppe (1970:49-50) also points out that compound words, foreign names and loanwords are not subject to vowel harmony.

As introduced in 1.1, Svantesson et al. (2005) use the feature [pharyngeal] to distinguish the same line Poppe uses to divide back and front vowels. The neutrality of [i] is attributed to its lack of pharyngeal counterpart (Svantesson et al. 2005). The concept of archiphonemes is also adopted by Svantesson et al. (2005) to encompass the variation of suffix vowels that do not have a clear underlying phoneme.

In Svantesson et al. 2005, vowel harmony is treated as the auto-segmental spreading of the features [pharyngeal] and [round] over the domain of the non-compound word. Only initial vowels with [pharyngeal] can act as triggers in the harmony process. The non-pharyngeal [e], [o], [u] cannot spread their [-pharyngeal] values. (This is an important point to be proved by the OT analysis of this study. I will take a detour first, insisting both [+pharyngeal] and [-pharyngeal] as harmony triggers. It is the failure of the latter approach to predict the suffix vowels for Mongolian that proves the validity of the former). To account for the transparency of [i], Svantesson et al. (2005) exclude the vowel from segments acting as targets.

Similarly for rounding harmony, only [+round] has the permission to spread, where the target vowels are limited to open vowels (Svantesson et al. 2005). The opacity of U (archiphoneme of [u] and [ʊ]) is explained by its inherent association to [+round] (Svantesson et al. 2005). Because of the overarching requirement that association lines cannot cross in segmental phonology, the spreading of [+round] stopped short at U (Svantesson et al. 2005). However, Svantesson et al. (2005) admit that this theory fails to makes sense of why initial U's do not spread their [+round] value to the next vowels (see (5c) and (5f)).

2.1 Why Optimality Theory?

One troubling aspect of reading Mongolian vowel harmony as feature spreading, is the singling out of [i] and U as exceptions. [i], [u], and [ʊ] are either excluded from the pool of trigger or target vowels. This approach certainly suffices for an introductory description of the eccentric behavior of Mongolian vowel harmony to a foreign learner of the language. However, it does not provide a natural explanation of what goes on in a native speaker's mind when they pronounce words. A theory ought to be sought to account for both the transparency of [i] and the opacity of U consistently, without treating them as any different than the other vowels. And an Optimality Theoretic (OT) analysis can do exactly that.

Vowel harmony is not unfamiliar with OT analysis. Studies have been conducted on Hungarian (Hayes & Londe 2006, Hayes et al. 2009), Finnish (Kiparsky & Pajusalu 2003, Smolensky 1993), Turkish (Kirchner 1993), to list a few, as well as typological investigation into the phenomenon itself (Kaun 1995). Yet there has never been any attempt to analyze Mongolian vowel harmony using OT in the record. In search for a consistent and congruous OT analysis of Mongolian vowel harmony, I have consulted the literature listed above.

2.2 A Note on Pharyngeal

The feature [pharyngeal] used in Svantesson et al. 2005 is also described as Retracted Tongue Root (RTR) in another chapter of the book. RTR is the opposite of Advanced Tongue Root (ATR). For the purpose of readability of this paper, I have decided to translate the feature [pharyngeal] into [-ATR], and label the non-pharyngeal vowels as [+ATR]. The various names of the same feature is only a matter of nominal technicality, having no effect on the analysis. The hope is that readers of this paper can think in terms of the more familiar and universal [ATR] and draw comparisons to other languages that have ATR harmony.

3. PHONEMES

I begin the OT analysis by examining monosyllabic stems with monosyllabic suffixes. In this formation, the stem vowel is a constant, allowing the full display of suffix vowel variation. The word lists used here are taken from Svantesson et al. 2005, with their pronunciation confirmed by the recording of my speaker. Three suffixes: direct past tense, causative, and accusative are selected to illustrate the full paradigm of variation.

(6) Monosyllabic verb stem + direct past tense suffix

	Monglian		English		Monglian		English
	IPA	Cyrillic			IPA	Cyrillic	
a	it-ɮe	идлээ	‘eat-DPST’	e	xʊnʲ-ɮa	хуньлаа	‘pleat-DPST’
b	uts-ɮe	үзлээ	‘see-DPST’	f	jaw-ɮa	явлаа	‘go-DPST’
c	xeeɮ-ɮe	хээллээ	‘decorate-DPST’	g	ɔr-ɮɔ	орлоо	‘enter-DPST’
d	og-ɮo	өглөө	‘give-DPST’				

(7) Monosyllabic verb stem + causative suffix

	Monglian		English		Monglian		English
	IPA	Cyrillic			IPA	Cyrillic	
a	it-uɮ	идүүл	‘eat-CAUS’	e	xʊnʲ-ʊɮ	хуниул	‘pleat-CAUS’
b	uts-uɮ	үзүүл	‘see-CAUS’	f	jaw-ʊɮ	явуул	‘go-CAUS’
c	xeeɮ-uɮ	хээлүүл	‘decorate-CAUS’	g	ɔr-ʊɮ	оруул	‘enter-CAUS’
d	og-uɮ	өгүүл	‘give-CAUS’				

(8) Monosyllabic noun stem + accusative suffix

	Monglian		English		Monglian		English
	IPA	Cyrillic			IPA	Cyrillic	
a	siɮ-ig	шилийг	‘glass-ACC’	e	sʊm-ig	сумыг	‘arrow-ACC’

b	sux-ig	сүхийг	‘axe-ACC’	f	ɢar-ig	гарыг	‘hand-ACC’
c	teeɮ-ig	дээлийг	‘gown-ACC’	g	ɔr-ig	орыг	‘place-ACC’
d	xoɮ-ig	хөлийг	‘foot-ACC’				

The direct past tense suffix in (6) has the variation /-ɮe ~ -ɮa ~ -ɮo ~ -ɮɔ/, while the causative suffix (7) alternates between /-uɮ ~ -ʊɮ/. The accusative suffix /-ig/ in (8), quite interestingly, stays the same throughout the paradigm.

The variation /e~a~o~ɔ/ of (6) is the result of both ATR harmony and rounding harmony at work. /u~ʊ/ in (7) shows only trace of ATR harmony, but not of rounding harmony. The suffix vowel [i] in (8) does not change, because it has neither ATR nor rounded counterpart to change into.

Even though [u] and [ʊ] in the stems in (6) refuse to take on a rounded vowel in the direct past tense suffix, they have no problem with [u] or [ʊ] in the causative suffix of (7). The vowel in the causative suffix has no [-round] counterpart to conform to the opacity demanded by the high rounded vowel in the stems. Similarly, but in a greater degree, the accusative suffix [i] not only has no [+round] counterpart, but also no [-ATR] counterpart, to meet the various harmonic needs of the stem vowels. Even though [i] can theoretically change into a high back vowel [u] to satisfy rounding harmony, and further into [ʊ] to satisfy ATR harmony, it does not. There seems to be an uncrossable line between the front and back areas in the high region of vowel space. The line between high vowels and non-high vowels (or open vowels, according to Svantesson et al. 2005), is also uncrossable. Otherwise [u] and [ʊ] in the causative suffix would simply descend to make themselves [-round] for [-round] stems. At the same time, the front and back line in the non-high region is almost non-existent. [e] can freely change into [o], and [a] into [ɔ] for rounding harmony. The vowel chart below illustrates the uncrossable barriers in double lines.

	-Round	+Round
+ATR	i	u
-ATR		ʊ
+ATR	e	o
-ATR	a	ɔ

Figure 2

3.1 FAITHFULNESS CONSTRAINTS

Translating the double lines of the vowel space into constraints, we have:

ID[HIGH]: Do not change the value of [high] of a vowel.

ID[BK]/[HI]: Do not change the value of [back] if the vowel is [+high].

These two faithfulness constraints are ranked very high, to prevent the vowels from crossing the boundaries to satisfy vowel harmony.

One may wonder why I do not simply write two separate faithfulness constraints, ID[HIGH] and ID[BACK], and rely on the magic of ranking to account for high vowels' greater aversion to a change in backness than non-high vowels. The frank answer is such a trick is impossible to be accomplished.

3.2 RICHNESS OF THE BASE

Although keeping my analysis in line with the principle of Richness of the Base (ROTB), the strict boundaries in vowel space mean that the input possibility of a given tableau can not be the exhaustion of every vowel in Mongolian. An ROTB analysis indeed require that, in a direct past tense tableau, any non-high vowel input would produce the same surface form. However, if a high front vowel [i] is thrown into the direct past tense tableau as a possible input, the candidate with [i] suffix would win, because the direct past tense tableau is subject to the same group of constraints and under the same ranking as the accusative tableau, which consistently crowns [i] as the winner.

The number of possible inputs for a suffix vowel, is only as many as the number of allophones within a single phoneme. Although ROTB rejects the idea of an underlying phoneme, it does not exist independently of the concept of phonemes overall. Only allophones of the surface forms we wish to produce can be allowed as experimental input. Therefore, for every surface form, the corresponding input vowels we need to investigate are plotted in the following table.

i	u	ʊ	e	a	o	ɔ	
Input Possibilities Needed to Consider for ROTB							Output
i							i
	u	ʊ					u
	u	ʊ					ʊ
			e	a	o	ɔ	e
			e	a	o	ɔ	a
			e	a	o	ɔ	o
			e	a	o	ɔ	ɔ

Table 1

4. A NOTE ON [i]

Before we plunge into a full analysis of markedness constraints and ranking, we need to give the vowel inventory some thoughts.

4.1 GAP IN THE VOWEL INVENTORY

Referring back to Figure 2, there is a gap in the vowel inventory, namely the absence of a high front unrounded [-ATR] vowel. All the other six vowels in the chart form [±ATR] pairs, but [i] has no [-ATR] counterpart.

The high front unrounded [-ATR] vowel is rare in the vowel inventories of world languages. This might be the result of the physical difficulty of producing such sounds. Developing the framework of Grounded Phonology, in which phonological conditions are physically grounded, Archangeli and Pulleyblank (1994) note from several sources that the tongue-raising gesture involved with [+high] tends to co-occur with the advancing of the tongue root in the oral cavity. This helps explain the absence of [-ATR] in the high front region of

Mongolian vowel inventory. Another insight from their work is the link between [-ATR] and [+low] (Archangeli & Pulleyblank 1994). Citing Halle & Stevens 1969, Archangeli and Pulleyblank (1994) report that when a speaker retracts their tongue root, the tongue body is more likely to be dragged downwards. This sheds light on why the [-ATR] counterpart of a mid front vowel [e] in Mongolian ATR harmony is actually [a], a low vowel.

Despite their rarity, high front unrounded vowels with [-ATR] value actually exist in world languages, usually noted with the IPA symbol [ɪ]. Okpe, Javanese, Kinande, Akan, and Maasai all have [ɪ] in their vowel inventories (Archangeli & Pulleyblank 1994). And In Javanese and Maasai, [ɪ] alternates with [i] in ATR harmony (Archangeli & Pulleyblank 1994).

Could the [i] in Mongolian [-ATR] words have a [-ATR] value as well, but has eluded the documentation of phonologists? A formant analysis of the recording of my speaker indeed shows a small difference in F1 between [i] in [+ATR] words (about 390Hz) and [i] in [-ATR] words (about 435 Hz). It is tempting to conclude that there is a [ɪ] to conform to [-ATR] spreading, but the difference is too small and the tokens too few to warrant such a decisive statement. Further acoustic studies may shed light on this matter.

There remains the possibility of a [ɪ] at an earlier stage of Monglian, lost through historical sound change. This actually happened in Ẹdoid languages (Elugbe 1983). Proto-Ẹdoid had a 10-vowel system, where both [i] and [ɪ] existed. However, out of the 20 present-day descendants of the proto-language, 14 have lost the [-ATR] ɪ (Elugbe 1983). The reason, according to Archangeli and Pulleyblank (1994), being that the feature [+high] and [-ATR] are antagonistic, the combination of them are much more likely to be lost through time.

However, an account of the vowel harmony shift which took place between Classical Mongolian and modern Khalkha Mongolian dismisses this possibility. In Classical Mongolian, the high vowel space consists of [i], [y] and [u] (Svantesson 1985). At the time, Classical Mongolian practiced front-back harmony, where [y] and [u] alternate between words with front and back vowels (Svantesson 1985). During the historical shift, [y] moved back to the position of [u], while [u] moved even further back into [ʊ] (Svantesson 1985). The current [+/-ATR] contrast in the high back area is a result of a chain of backing movements. No [ɪ] has existed at an earlier stage of the language to be lost in the first place.

Interestingly, another descendent of Classical Mongolian, Shuluun Höh Mongolian, has developed a contrast between [+ATR] [i] and [-ATR] [ɪ], where ATR harmony is practiced in the high front area (Svantesson 1985). This further proves that [-ATR] [ɪ] is a later innovation, which is unlikely to be present in the two dialect's common ancestor language, Classical Mongolian, or even Ancient Mongolian.

Even with the frequency difference being minimal, it is still tempting to make a distinction between the two i's that appear alongside vowels of differing category. Assigning different feature values to the same surface form is not unprecedented. Within the framework of "combinatory specification" of F-elements proposed by Archangeli and Pulleyblank (1994), they account for two differing phonological behaviors seen in the vowel [i] of Barrow Inupiaq by separating the vowel into /i_1/ with F-element [-back], and an abstract /i_2/ that has no F-element at all. Similarly, one could argue that Mongolian has a [+ATR] /i_1/, and a [-ATR] /i_2/, to conform to the [ATR] value of the words they are situated in. This approach would make constraints easier to write as well. However, it is an over-simplistic method that has significant implications. To say that the [i] in the sequence […a…i…] is [-ATR] seems logical enough, but to say that the same vowel is [-ATR] in […i…a…] is quite anachronistic in terms of the real time a speaker articulates these two vowels. How can they know the [i] is [-ATR] before reaching to a [-ATR] vowel. Of course, this could lead to a long discussion on underspecification. But the OT analysis presented in this study actually accounts for [i] transparency without such complications.

4.2 The Transparency of [i]

Mongolian is not the only language where the high front unrounded vowel is transparent to vowel harmony.[i] in Hungarian is transparent to backness harmony (Ringen & Kontra 1989).

Smolenksy (1993) attributes transparency to gaps in vowel inventory. If a gap renders a feature value -F redundant for a vowel, then the spread of +F "often operate as though the redundant -F were absent" (Smolensky 1993). Extrapolating this point to Mongolian, we can say that [-ATR] is the feature that spreads. The [+ATR] [i] has no [-ATR] counterpart to distinguish itself from, rendering the feature [+ATR] redundant, which is ignored by [-ATR] when it spreads.

Kiparsky and Pajusalu (2003) also identify one of the source of neutrality (transparency or opacity) of a vowel as the absence of a harmonic counterpart in the vowel inventory. They use the “featural markedness constraint” to make sure that the candidate with the gap vowel, perfect for vowel harmony does not win (Kiparsky & Pajusalu 2003). An example they give is

$$\begin{bmatrix} \text{-low} \\ \text{-round} \end{bmatrix} \text{==> [-back]}$$

If a vowel is non-low and unrounded, it cannot be back, which rules out *[ɨ] (Kiparsky & Pajusalu 2003). Following this structure, I propose:

$$\begin{bmatrix} \text{+front} \\ \text{+high} \end{bmatrix} \text{==> [+ATR]}$$

If a vowel is front and high, it cannot be [-ATR]. To use this constraint to rule out [ɪ], it must be ranked at the very top. Because of the regularity and consistency with which it stops [ɪ] from ever surfacing in Mongolian, I have decided not to reiterate it in the tableaux in this paper.

5. OT for ATR Harmony

Breaking down the OT analysis of Mongolian vowel harmony, I begin with ATR harmony. And in order to cancel out the “noise” of rounding harmony, I have decided to illustrate ATR harmony with the causative suffix in (7). The suffix vowel alternates between [u] and [ʊ], which is not affected by rounding harmony, as the two vowels have no unrounded counterparts to change into. Referring back to Table 1 of possible inputs, the only input vowels considered here are [u] and [ʊ].

Out of the seven suffix vowel candidates, five are ruled out from the beginning, because of the two faithfulness constraints, which is shown in the incomplete Tableaux 1 and 2.

/u/	ID[HIGH]	ID[BK]/[HI]	…
[i]		*!	
[u]			
[ʊ]			
[e]	*!		
[a]	*!		
[o]	*!		
[ɔ]	*!		

Tableau 1

/ʊ/	ID[HIGH]	ID[BK]/[HI]	…
[i]		*!	
[u]			
[ʊ]			
[e]	*!		
[a]	*!		
[o]	*!		
[ɔ]	*!		

Tableau 2

Summarizing the vowel sequences in (7), we have:

[+ATR]…[+ATR]	[-ATR]…[-ATR]
i…u	
e…u	a…ʊ
u…u	ʊ…ʊ
o…u	ɔ…ʊ

Table 2

There seems to exist a consistent [ATR] agreement between the two vowels of a causative verb. Therefore an agree constraint is naturally proposed:

AGR[ATR]: Vowels in the same word have to agree in their value for the feature [ATR].

Accompanying the markedness constraint is the faithful constraint:

ID[ATR]: Do not change the [ATR] value of a vowel.

Because the faithful candidate cannot always win, otherwise the two possible inputs considered here: /u/ and /ʊ/ would produce two completely different outputs for the same word,

ID[ATR] needs to be ranked below **AGR[ATR]**.

	/e…u/	ID[HIGH]	ID[BK]/[HI]	AGR[ATR]	ID[ATR]
☞	[e…u]				
	[e…ʊ]			*!	*
	…	*!			

Tableau 3

	/e…ʊ/	ID[HIGH]	ID[BK]/[HI]	AGR[ATR]	ID[ATR]
☞	[e…u]				*
	[e…ʊ]			*!	
	…	*!			

Tableau 4

	/a…u/	ID[HIGH]	ID[BK]/[HI]	AGR[ATR]	ID[ATR]
	[a…u]			*!	
☞	[a…ʊ]				*
	…	*!			

Tableau 5

	/a…ʊ/	ID[HIGH]	ID[BK]/[HI]	AGR[ATR]	ID[ATR]
	[a…u]			*!	*
☞	[a…ʊ]				
	…	*!			

Tableau 6

Tableaux 3-6 are in line with ROTB, illustrating the ATR-related constraints and ranking at work. The suffix vowel candidate that agrees with the [ATR] value of the stem always wins, no matter whether the input is [+ATR] or [-ATR].

5.1 Trisyllabic Words

However, this structure runs into trouble as soon as it is tested against trisyllabic words formed by a disyllabic stem and a monosyllabic suffix. Now, remember that [i] in a monosyllabic stem selects [+ATR] vowels to follow, which has been shown in the words from (6) and (7). However, this rule seems to be only strict on the process of selecting vowels in a suffix. Within a disyllabic stem, an initial i is perfectly happy with taking on a [-ATR] vowel, as manifested in the reflexive form of ‘guitar’.

(9)	Mongolian IPA	Mongolian Cyrillic	English		Mongolian IPA	Mongolian Cyrillic	English
a	git	гитараа	‘guitar-RFL’	b	awir-ax	авирах	‘to ascend’

The suffix vowel [a] has no motivation to become rounded, nor is it allowed to rise, therefore we do not need to consider any candidate or input other than [e] and [a]. Is the current

OT ranking able to produce the correct output?

	/i…a…e/	ID[HIGH]	ID[BK] /[HI]	AGR[ATR]	ID[ATR]
*☞	[i…a…e]			*	
	[i…a…a]			*	*!
	…	!*			

Tableau 7

	/a…i…e/	ID[HIGH]	ID[BK] /[HI]	AGR[ATR]	ID[ATR]
*☞	[a…i…e]			*	
	[a…i…a]			*	*!
	…	!*			

Tableau 8

Note that from now on, only the vowel that is most distant from the winner, in terms of features, is to be considered as input. This is to maximize the winner's violations of faithfulness constraints, thus amplifying the relative ranking between a pair of markedness constraint and faithfulness constraint. Here, with knowledge that the surface form is the vowel [a], [e] is chosen as the input to test out the validity of the ranking between AGR[ATR] and ID[ATR].

Neither Tableau 7 nor 8 can predict the right winner. Both candidates in each tableau violate AGR[ATR], rendering the markedness constraint silent. The decision is left to the faithfulness constraint which blindly choose the input form, ignoring vowel harmony altogether.

5.2 Local vs Distal

To resolve the incompetence of AGR[ATR] at stopping *[i…a…e] and *[a…i…e] from winning, its definition requires readjustment.

The first problem to notice is that in Tableau 7, the markedness constraint punishes *[i…a…e] and [i…a…a] equally, assigning one count of violation to both candidates. The same can be said for *[a…i…e] and [a…i…a] in Tableau 8. Some method of measuring the severity of a candidate's violation needs to be devised.

For the pair of candidates in Tableau 7, [e] violates AGR[ATR] because it disagrees with its immediate neighbor [a] in [ATR], but consistent in [-ATR] with the initial vowel [i]. [a] does not differ from its immediate neighbor [a], yet it disagrees with the initial [+ATR] [i]. A single agreement constraint fails to count and weigh the different scenarios of disagreement. To remedy this, I have decided to borrow the concept of LOCAL vs DISTAL constraints from Hayes and Londe (2006). In their study on the free variation of Hungarian vowel harmony in multi-syllabic words, Hayes and Londe (2006) label constraints that punish disharmony between neighboring vowels as LOCAL, and label constraints that punish disharmony between vowels that have at least one syllable in between as DISTAL.

Extrapolating the distinction into Mongolian, I have come up with the following two constraints:

AGR[ATR]LOCAL: A non-initial vowel has to have the same [ATR] value as the vowel in the syllable immediate to its left.

AGR[ATR]DISTAL: A non-initial vowel has to have the same [ATR] value as the initial vowel.

For [i…a…a] to win over *[i…a…e], the harmony between neighboring vowels needs to be prioritized over the arching harmony established on the initial vowel. Therefore AGR[ATR]LOCAL outranks AGR[ATR]DISTAL, which is shown in Tableau 9.

	/i…a…e/	ID[HIGH]	ID[BK]/ [HI]	AGR[ATR] LOCAL	AGR[ATR] DISTAL	ID[ATR]
	[i…a…e]			**!	*	
☞	[i…a…a]			*	**	*
	…	!*				

Tableau 9

However, for [a…i…a] to win over *[a…i…e], AGR[ATR]LOCAL has to be ranked below AGR[ATR]DISTAL. The sequence [a…i…a] changes its [ATR] value twice, whereas *[a…i…e] only once.

	/a…i…e/	ID[HIGH]	ID[BK]/ [HI]	AGR[ATR] DISTAL	AGR[ATR] LOCAL	ID[ATR]
	[a…i…e]			**!	*	
☞	[a…i…a]			*	**	*
	…	!*				

Tableau 10

The constraint rankings of Tableaux 9 and 10 are fundamentally at odds with each other,. It is only when LOCAL outranks DISTAL that [i…a…]a wins, and it is only when DISTAL outranks

LOCAL that [a…i…a] wins. The LOCAL vs DISTAL distinction appears unable to account for Mongolian ATR harmony.

5.3 AGREE VS EXTEND

Another angle to approach the problem is to examine the [ATR] value of each of the vowel in the two sequences.

(10)

i	…	a	⁞	…	a		a	…	i	⁞	…	a
[+ATR]		[-ATR]	⁞		[-ATR]		[-ATR]		[+ATR]	⁞		[-ATR]

The sequence of the vowel stem seems to be of little importance to the suffix vowel, determined to be [-ATR] as long as there is some [-ATR] element in the stem. The suffix vowel does not have allegiance to either its immediate neighbor or the initial vowel. Instead, it derives its [ATR] value from the stem as a whole, which in turn is not defined by the [ATR] value of the initial vowel.

From the point of view of the stem itself — if it is a bullet that runs from left to right in the temporal sequence of articulation, it appears quite ready to depart from the [+ATR] of its initial vowel, as soon as a [-ATR] vowel comes into view. A Mongolian word becomes [-ATR] as soon as it comes across a [-ATR] vowel. And it is [+ATR] otherwise. [-ATR] is the feature that triggers spreading, whereas [+ATR] is the default value when there is no trigger.

To get a clearer picture of the relationship between [+ATR] and [-ATR], imagine a carpet sitting flat on the floor. This is when a word is at its default setting, [+ATR]. Now, imagine a builder pinning the carpet to the floor who left a small glass ball under the carpet by accident. Then a cleaner comes and vacuums the carpet, who goes from the left hand side to the right. The vacuum is so close to the carpet that it flattens out the carpet wherever it goes. And when it encounters the glass ball, it pushes it rightwards (Figure 3).

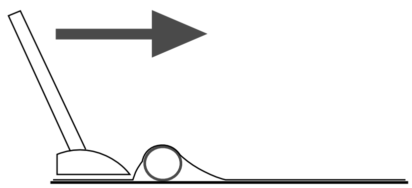

Figure 3

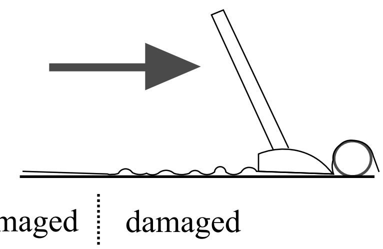

Figure 4

No matter where the glass ball is, it will be pushed rightward, damaging the carpet along its path (Figure 4). Of course, it can be originally on the very left end of the carpet. But it can also be situated in the middle of the carpet, damaging only the portion of the carpet to its right.

In this analogy, the carpet is a Mongolian word. The flatness is its default [+ATR] position. The glass ball is the outstanding [-ATR] trigger, the vacuum cleaner the harmonizing force, and the damaged carpet traces of [-ATR] spreading. And the important lesson learned is that to the left of the initial position of the ball, the flat carpet has no reason to appear damaged. This is the reason why the [+ATR] [i] is allowed to precede a string of [-ATR] vowels.

To capture the rightward spreading of the trigger [-ATR], we have:

EXT[-ATR]: If a vowel is [-ATR] anywhere in the word, then all vowels on its right hand side must be [-ATR] as well. A violation occurs if a [+ATR] vowel follows a [-ATR] vowel, regardless of the distance between them.

Note that the counting of violations anchors upon the [+ATR] vowels that disrupt the [-ATR] spread. One [+ATR] to the right of a [-ATR] vowel count as one violation, and two [+ATR] vowels count as two violations. The number of preceding [-ATR] vowels have no effect on the number of violations.

To translate the default [+ATR] status of a word into constraint, and to counter the power of EXT[-ATR], there is:

***[-ATR]**: Do not have [-ATR] vowels. A violation occurs when there is a [-ATR] vowel anywhere in the word.

It goes without saying that EXT[-ATR] has to outrank *[-ATR], otherwise the feature would never be allowed to spread. Therefore we have the following tableaux, predicting successfully the win of [i…a…a] and [a…i…a].

	/i…a…e/	ID[HIGH]	ID[BK]/ [HI]	EXT[-ATR]	*[-ATR]	ID[ATR]
	[i…a…e]			*!	*	
☞	[i…a…a]				**	*
	…	!*				

Tableau 11

	/a…i…e/	ID[HIGH]	ID[BK]/ [HI]	EXT[-ATR]	*[-ATR]	ID[ATR]
	[a…i…e]			**!	*	
☞	[a…i…a]			*	**	*
	…	!*				

Tableau 12

I have proved why *[-ATR] and ID[ATR] need to be ranked below EXT[-ATR] individually, but there has yet been any discussion on the relative ranking between the two. Interestingly, evidence comes from a disyllabic [+ATR] sequence.

	/e…a/	ID[HIGH]	ID[BK]/ [HI]	EXT[-ATR]	*[-ATR]	ID[ATR]
☞	[e…e]					*
	[e…a]				*!	
	…	!*				

Tableau 13

As it turns out, *[-ATR] needs to outrank ID[ATR], so that in a [+ATR] word, a [-ATR] suffix vowel does not spring from nowhere, unchecked and copying faithfully the [+ATR] value of the input vowel.

In the spirit of extra caution, let me illustrate how the ranking of the three constraints can predict the correct surface form of a disyllabic [+ATR] word as well.

/a…e/	ID[HIGH]	ID[BK]/[HI]	EXT[-ATR]	*[-ATR]	ID[ATR]
[a…e]			*!	*	
☞ [a…a]				**	*
…	!*				

Tableau 14

6. OT for Rounding Harmony

Given that [i] is also transparent in rounding harmony, and that both [i..o] and [o..i] stems select for a rounded suffix vowel [o] instead of the unrounded [e] in (11), we can transplant EXT[-ATR] and *[-ATR] to rounding harmony too.

(11)	Mongolian IPA	Mongolian Cyrillic	English		Mongolian IPA	Mongolian Cyrillic	English
a	int	интоороо	'cherry-RFL'	b	poor-ig-o	бөөрийгөө	'kidney-ACC-RFL'

EXT[+RD]: If a vowel is rounded anywhere in the word, then all vowels on its right hand side must be rounded as well. A violation occurs if an unrounded vowel follows a rounded vowel, regardless of the distance between them.

***[+RD]**: Do not have rounded vowels. A violation occurs when there is a rounded vowel anywhere in the word.

ID[RD]: Do not change the roundness of a vowel.

The same ranking argument from ATR harmony still stands. *[+RD] has to rank lower than EXT[+RD], otherwise rounding harmony would never take place. ID[RD] needs to rank lower than EXT[+RD] as well, so that the winner is not a direct copy of the input form. In addition, *[+RD] outranks ID[RD] to stop a *[e…o] sequence from surfacing. The following tableaux illustrate the ranking of the constraints at work.

	/o…i…e/	ID[HIGH]	ID[BK]/[HI]	EXT[+RD]	*[+RD]	ID[RD]
☞	[o…i…e]			**!	*	
	[o…i…o]			*	**	*
	…	!*				

Tableau 15

	/i…o…e/	ID[HIGH]	ID[BK]/[HI]	EXT[+RD]	*[+RD]	ID[RD]
	[i…o…e]			*!	*	
☞	[i…o…o]			*	**	*
	…	!*				

Tableau 16

	/e…o/	ID[HIGH]	ID[BK]/[HI]	EXT[+RD]	*[+RD]	ID[RD]
☞	[e…e]					*
	[e…o]				*!	
	…	!*				

Tableau 17

	/o…e/	ID[HIGH]	ID[BK]/[HI]	EXT[+RD]	*[+RD]	ID[RD]
	[o…e]			*!	*	
☞	[o…o]				**	*
	…	!*				

Tableau 18

6.1 UNIFORM[RD]

What is really intriguing about the rounding harmony of Mongolian is the opacity of high back vowels. The current constraints have no way of stopping the sequence *[u…o] from surfacing, instead of the attested [u…e]. In search of a mechanism that creates the opacity of [u] and [ʊ], I have consulted a piece of typological literature on vowel harmony by Kaun (1995).

Kaun (1995) claims that vowel harmony is a way for languages to maximize the perceptual distinction of a certain feature, by prolonging the duration of the feature throughout the whole word. Evidence from articulatory phonetics confirms this form of prolonging of articulation. Boyce (1990) observes that when English (with no rounding harmony) and Turkish (with rounding harmony) speakers are asked to produce a VCV sequence where both vowels are rounded, they display different articulatory gestures. The English speakers protrude their lips twice for the two rounded vowels, separated by another gesture which produces the consonant (Boyce 1990). The Turkish speakers, on the other hand, protrude their lips only once, and retain the protrusion even during the articulation of the intermediate consonant (Boyce 1990).

Therefore, Kaun (1995) reasons, it is only natural to find the two rounded vowels on either side of the intermediate consonant to be exactly the same in Turkish, given they are produced with one single articulatory gesture. In Mongolian, the [+high] [u] and [-high] [o] differ in articulatory gestures. Thus the sequence *[u…o] cannot possibly be produced by a rounding harmony which is motivated by the prolonging of one single articulatory gesture.

Kaun (1995) proposes the constraint **UNIFORM [RD]** and defined it as “the autosegmental [+round] may not be multiply linked to slots bearing distinct feature specifications” .

UNIFORM[RD] is linked with “crowding” in vowel inventory (Kaun 1995). Most of the languages with rounding harmony, where the trigger is a [-high] vowel and the target a [-high] vowel, have a crowded mid and low vowel space and a sparse high region (Kaun 1995). The reason for this ties back to vowel harmony as prolonging the duration of a certain feature. Kaun (1995) argues that it is only when the feature is perceptually difficult that such a measure is needed. In her own words, “in a vowel system with only i and u in the high region, the round vs unround distinction presumably poses no serious perceptual challenge” (Kaun 1995). This explains why only open vowels are subject to rounding harmony in Mongolian.

Incorporating UNIFORM[RD] to the existing rounding constraints, the next step is to figure out its position in the ranking. For UNIFORM[RD] to fully function, it has to outrank EXT[-RD], or else *[u…o] and *[ʊ…ɔ] would win.

/u…o/	ID[HIGH]	ID[BK]/[HI]	UNIF[RD]	EXT[+RD]	*[+RD]	ID[RD]
☞ [u…e]				*	*	*
[u…o]			*!		**	
…	!*					

Tableau 19

As I have mentioned, the transparency of [i] is special in that it also passes on the opacity of [u] and [ʊ] with fidelity. We need to revise the definition of UNIFORM[RD] to accommodate Mongolian transparency:

> **UNIFORM[RD]**: If there are two rounded vowels in a word, they have to agree in [HIGH], regardless of the distance between them.

/u…i…o/	ID[HIGH]	ID[BK]/[HI]	UNIF[RD]	EXT[+RD]	*[+RD]	ID[RD]
☞ [u…i…e]				**	*	*
[u…i…o]			*!	*	**	
…	!*					

Tableau 20

7. OT RANKING

Now it is time to combine the constraints for ATR harmony and rounding harmony. The pair of faithfulness constraints, ID[HIGH] and ID[BK]/[HI], have established their priority over ATR and rounding constraints. The ATR constraint rankings, and the rounding constraint rankings, are already in place, which can be summarized in the diagram below:

(13) EXT[-ATR] >> *[-ATR] >> ID[ATR]

{ID[HIGH], ID[BK]/[HI]}

UNIFORM[RD] >> EXT[+RD] >> *[+RD] >> ID[RD]

The question remains whether there are any interactions between any one of the ATR constraints and one from the rounding constraints. The straightforward answer is that there does not seem to be. The ATR value of any vowel in a word has no effect on the roundness of any of the vowels in the same word. And vice versa. Therefore we can smash the two tiers of constraints from (13) onto one level, while retaining the critical ranking of each tier.

(14)

{ID[HIGH], ID[BK]/[HI]}>>{UNIFORM [RD], EXT[-ATR]} >> {EXT[+RD], *[-ATR]} >> {*[+RD], ID[ATR]} >> ID[RD]

Note that for each ATR constraint, its namesake in the rounding constraints is always situated one stratum lower. This is because of the extra UNIFORM[RD] in the rounding constraints, which needs to be ranked high to ensure [u]/[ʊ] opacity, ending up disrupting the otherwise perfectly-aligned strata.

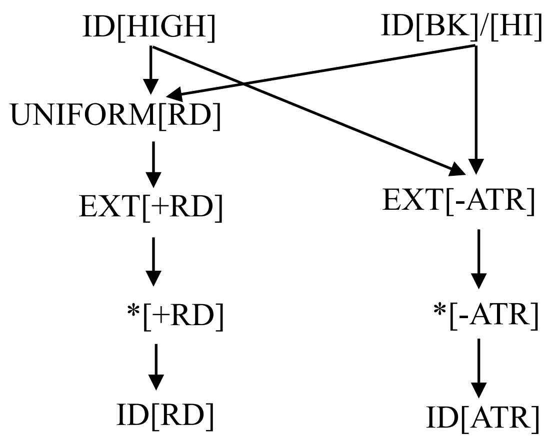

Figure 5

To show the ranking at work, I present the following tableaux:

	/ɔ…e/	ID[HI]	ID[BK]/ [HI]	UNIF [RD]	EXT [-ATR]	EXT [+RD]	*[-ATR]	*[+RD]	ID[ATR]	ID[RD]
	[ɔ…i]	*!			*	*	*	*		
	[ɔ…u]	*!			*		*	**		*
	[ɔ…ʊ]	*!					**	**	*	*
	[ɔ…e]				*!	*	*	*		
	[ɔ…a]					*	**!	*	*	
	[ɔ…o]				*!		*	**		*
☞	[ɔ…ɔ]						**	**	*	*

Tableau 21

/ʊ…o/	ID[HI]	ID[BK]/[HI]	UNIF [RD]	EXT [-ATR]	EXT [+RD]	*[-ATR]	*[+RD]	ID[ATR]	ID[RD]
[ʊ…i]	*!			*	*	*	*		*
[ʊ…u]	*!			*		*	**		
[ʊ…ʊ]	*!					**	**	*	
[ʊ…e]				*!	*	*	*		*
☞ [ʊ…a]					*	**	*	*	*
[ʊ…o]			*!	*		*	**		
[ʊ…ɔ]			*!				**	*	

Tableau 22

/i…ɔ/	ID[HI]	ID[BK]/[HI]	UNIF [RD]	EXT [-ATR]	EXT [+RD]	*[-ATR]	*[+RD]	ID[ATR]	ID[RD]
[i…i]	*!							*	*
[i…u]	*!						*	*	
[i…ʊ]	*!					*	*		
☞ [i…e]								*	*
[i…a]						*!			*
[i…o]							*	*!	
[i…ɔ]						*!	*		

Tableau 23

/i…ɔ…e/	ID[HI]	ID[BK]/[HI]	UNIF [RD]	EXT [-ATR]	EXT [+RD]	*[-ATR]	*[+RD]	ID[ATR]	ID[RD]
[i…ɔ…i]	*!			*	*	*	*		
[i…ɔ…u]	*!		*	*		*	**		*
[i…ɔ…ʊ]	*!		*			**	**	*	*
[i…ɔ…e]				*!	*	*	*		
[i…ɔ…a]					*	**!	*	*	
[i…ɔ…o]				*!		*	**		*
☞ [i…ɔ…ɔ]						**	**	*	*

Tableau 24

/ʊ…i…o/	ID[HI]	ID[BK]/[HI]	UNIF [RD]	EXT [-ATR]	EXT [+RD]	*[-ATR]	*[+RD]	ID[ATR]	ID[RD]
[ʊ…i…i]	*!			**	**	*	*		*
[ʊ…i…u]	*!			**	*	*	**		
[ʊ…i…ʊ]	*!			*	*	**	**	*	
[ʊ…i…e]				**!	**	*	*		*
☞ [ʊ…i…a]				*	*	**	*	*	*
[ʊ…i…o]			*	*!*	*	*	**		
[ʊ…i…ɔ]			*	*!	*	**	**	*	

Tableau 25

8. CONCLUSION

In this paper, I have proposed a working OT analysis of Mongolian vowel harmony. Agreement constraints are explored, only to prove its invalidity, and thus confirming the feature spreading analysis in which only [-ATR] and [+RD] are harmony triggers. Unlike previous literature written on Mongolian vowel harmony, my OT analysis manages to consistently predict the surface forms without putting the transparency of [i] and the opacity of [u] and [ʊ] to a side basket or with ad hoc rules. The high vowels in my analysis are not treated as exceptions to triggers or targets, but participate in vowel harmony just like any other vowel. To achieve that, two highly-ranked faithfulness constraints are put in place to forbid the high vowels from trespassing the boundaries in the vowel space, just to conform to the feature spreading of [-ATR] or [+RD]. The opacity of [u] and [ʊ], are accounted for by UNIFORM[RD] borrowed from Kaun (1995). The transparent [i] itself does not participate in any type of harmony, because of a gap in the vowel inventory. Its ability to pass on the information to the next vowel, including the information of [u]/[ʊ] opacity, is achieved by the two pairs of markedness constraints, EXT[-ATR] and *[-ATR], as well as EXT[+RD] and *[+RD]. These four constraints ensure that the default state of a vowel is [+ATR] and [-RD], allowing the ATR and unrounded [i] to exist alongside [-ATR] and [+RD] vowels.

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