Yakut Vowel Harmony in Harmonic Grammar
ヤクート語母音調和の解析： 調和文法からのアプローチ

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要旨

本稿の目的は、調和文法（Harmonic Grammar（Pater 2009, 2016）、以下 HG）を用いてトルコ系言語の一つであるヤクート（サハ）語の母音調和のパターンを解析することである。ヤクート語では、語中の母音は原則として共通の［円唇］（[round]）の属性を共有するが、円唇非高母音（non-high round vowels）は、円唇高母音（[+high, round]）の後に続くことができないという制限がある。本稿で用いる HG は最適性理論（以下 OT）同様、制約（constraint）を基にした音韻理論であるが、OT と違い制約の違反にはウェイトがかけられている。すなわち OT のように全ての制約の違反が等しいのではなく、制約のウェイトにより出力候補には異なった数値のペナルティが与えられる。本稿では、SPREAD [ROUND]（[round] 属性を拡散せよ）を IDENT [ROUND]（入力と出力の [round] 属性はお互いに忠実である）よりウェイトを重くすることにより母音調和を引き起こし、ヤクート語に見られる円唇非高母音の出没制限は、SPREAD [ROUND] の違反に対する gang up effect（より軽いウェイトの制約の違反の累積により、より重いウェイトの制約の違反を覆す）によって説明可能であることを示す。

Keywords : Harmonic Grammar, weighted constraints, vowel harmony, Yakut（Sakha）

1. Introduction

Yakut（also known as Sakha）is a West Turkic language spoken in Siberia, and it is one of the major languages in Sakha Republic. One of the phonological characteristics of Yakut is the existence of vowel harmony, specifically, backness and roundness harmony.

A number of formal phonological analyses have been proposed to account for the vowel harmony patterns of Yakut（Kaun 1995, Sasa 2001 and 2009）, and the main goal of this squib is to examine whether Harmonic Grammar（henceforth HG）（Pater 2009, 2016）can be applied to accounting for Yakut roundness harmony. The core assumption of HG is that constraints are weighted, and it has been shown that weighted constraints are successful in accounting for the transparency vowel harmony pattern observed in Hungarian（Hayes and Londe 2007）. However, not much research has been done to examine whether weighted constraints are applicable to（more）general vowel harmony patterns.

In this article, Yakut vowel harmony is used as an example to see if HG is successful in providing the phonological analyses of more general vowel harmony patterns. It is demonstrated that HG is successful in accounting for the attested vowel harmony

patterns of Yakut. The organization of this article is as follows. Yakut data exhibiting backness and roundness harmony are presented in Section 2. Section 3 presents two analyses of Yakut roundness harmony; Section 3.1. presents an overview of HG and the illustration of how HG accounts for the basic roundness harmony pattern of Yakut. Section 3.2. presents the HG treatment of the height restriction on Yakut roundness harmony. Section 4 presents some conclusions and points for further investigation.

2. Yakut Data

Yakut is a Turkic language spoken in Siberia. It is one of the major languages of the Republic of Sakha and it is spoken by approximately 450,000 speakers (Ebata 2021: 1).

(1) Map of Sakha and Yakutsk
(From Wikipedia; https://commons.wikimedia.org/wiki/File:Lena_watershed.png)
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In the map, the territory of the Sakha Republic is shown in yellow. Yakutsk is the capital of the Sakha Republic.

The Yakut vowel inventory is presented in (2). In this article, the feature [round] is assumed to be privative; that is, it is only the [(+) round] feature that is active in the grammar, and only the [round] feature is assumed to 'spread' in vowel harmony.

(2) Yakut Vowel Inventory

	[-back]		[+back]	
		[round]		[round]
[+hi]	i	y	ɨ	u
[-hi]	e	œ	a	o

In Yakut, there are two types of vowel harmony: backness and roundness harmony. Examples illustrating backness harmony are presented in (3); in (3), the accusative

(acc.) suffix, which consists of a high vowel, is realized differently depending on the backness specification of the vowel in the root. As seen in (3), there are no exceptions in backness harmony, and all of the vowels in the word agree in the backness specification.

(3) Yakut Backness Harmony (Ebata 2021: 13)

a) et 'meat'	et-i 'meat-acc.'
b) œŋ 'color'	œŋ-y 'color-acc'
c) at 'horse'	at-ɨ 'horse-acc'
d) ot 'grass'	ot-u 'glass-acc'

Yakut vowel harmony is root-controlled, and the first vowel in the root, or the vowel in the first syllable of a word, determines the backness of the rest of the vowels in a word. In (3a) and in (3b), all of the vowels in the word are [-back] because the root contains a [-back] vowel. Likewise, the accusative suffix is [+back] in (3c) and in (3d) because of the [+back] vowel in the root.

Yakut also exhibits roundness harmony, in which vowels in a word agree in roundness. Examples illustrating roundness harmony are presented in (4). In (4c) and in (4d), the accusative suffix begins with the nasal [n] since the root ends with a vowel.

(4) Yakut Roundness Harmony (Krueger 1962: 82-84)

a) tynnyk 'window'	tynnyk-y 'window-acc.'
b) murun 'nose'	murun-u 'nose-acc.'
c) bœrœ 'wolf'	bœrœ-ny 'wolf-acc.'
d) oʏo 'child'	oʏo-nu 'child-acc.'
e) kinige 'book'	kinige-ni 'book-acc.'
f) aʏa 'father'	aʏa-nɨ 'father-acc.'

As in backness harmony, the roundness of the vowel in the accusative suffix is determined by the roundness of the first vowel of the word. In (4a) through (4d), the accusative suffix contains a [round] vowel since the first vowel of the word is [round]. If the first vowel of the word is not round, the accusative suffix contains a non-round vowel as seen in (4e) and in (4f). Thus, the roundness of high vowels is predictable in suffixes, and high vowels are round when preceded by another round vowel.

However, unlike backness harmony, roundness harmony is restricted. When the suffix contains a [-high] vowel, the suffix vowel is not round even when the root contains a round vowel. This restriction is illustrated in the forms in (5). In (5), roots are followed by a suffix which contains a non-high vowel.

(5) Restriction on Roundness Harmony (Krueger 1962: 84-85, Kaun 1995: 23)

a) tynnyk- 'window'	tynnyk-ler (*tynnyk-lœr) 'window-plural'
b) tobuk- 'knee'	tobuk-ka (*tobuk-ko) 'knee-dative'
c) oju:n- 'shaman'	oju:n-tan (*oju:n-ton) 'shaman-ablative'
d) y:t- 'milk'	y:t-yen (*y:t-yœn) 'milk-instrumental'

In (5), since the root contains (a) round vowel(s), roundness harmony is expected to occur. However, the vowels in the suffixes in (5) are all non-round. According to Kaun (1995), the occurrence of [-high, round] vowels is restricted in roundness harmony, and they are allowed when they are preceded by a [-high, round] vowel. Thus, the non-high vowels in the suffixes in (5) are non-round because they are preceded by a high vowel in the root (as in (5a) through (5c)) or in the same suffix (as in (5d)). The attested and unattested roundness harmony patterns are summarized in (6).

(6) Summary of Roundness Harmony ('>' means *precedes*)

[+hi, round] >[+hi, round]	[+hi] > [-hi]	[-hi] > [+hi]	[-hi] > [-hi]
✓ (allowed)	* (not allowed)	✓ (allowed)	✓ (allowed)

([+hi] > [-hi]; a [+high, round] vowel precedes a [-high, round] vowel.)

(6) shows, first, that there are no restrictions on the occurrence of [+hi, round] vowels in roundness harmony. That is, the suffix [+high] vowel is realized as [round] when the preceding root vowel is [round]. Second, the roundness of the [-high] vowel in the suffix depends on the height of the preceding root vowel; when the root vowel is [-high, round], the vowel in the suffix is [round]. On the other hand, if the vowel in the root is [+high, round], the [-high] vowel in the suffix is not round. As a result, disharmonic forms result.

Two types of vowel harmony in Yakut have been discussed in this section; backness harmony is exceptionless while roundness harmony is restricted. As discussed in this section, the occurrence of [-high, round] vowels is restricted in roundness harmony in Yakut. In the next section, Yakut roundness harmony is analyzed within the mechanism of HG. Section 3.1. presents the preliminary analysis of Yakut roundness harmony to demonstrate the basic mechanism of HG. The full analysis of roundness harmony, focusing on the restricted occurrence of non-high round vowels, is presented in Section 3.2.

3. An HG Approach to Yakut Roundness Harmony

3.1. Preliminaries: Overview of HG and Basic Yakut Roundness Harmony

The purpose of this section is to present the basic assumptions of HG. As mentioned, weighted constraints, one of the fundamental mechanisms of HG, have proven to be successful in accounting for Hungarian vowel harmony (Hayes and Londe 2007), and

this section presents how HG accounts for the basic Yakut roundness harmony pattern.

As Pater (2016) points out, HG is similar to Standard Optimality Theory (OT) in that both HG and Standard OT are constraint-based, rather than rule-based. Thus, the same constraints from Standard OT are assumed in HG. For the analysis of Yakut roundness harmony, Sasa (2009) presents an analysis within Standard OT with the constraints below.

(7) **IDENT σ1 [ROUND]** (Beckman 1997, 1998)

Segments in the initial syllable of a word in the output have the same specification as their input correspondents for the feature [round].

As discussed, Yakut vowel harmony is root-controlled and the vowel in the first syllable of a word determines the roundness of other vowels in a word. In other words, the first vowel of a word is the trigger of the harmony, and it never undergoes the harmony process. Hence, the Input-Output roundness identity is maintained in the vowel of the first syllable of a word.

Various proposals have been made to enforce harmony in OT. In this article, the markedness constraint in (8) is used. However, this does not necessarily mean that the analysis with SPREAD is better than other analyses.

(8) **SPREAD [ROUND]** (Padgett 1997, 2002; Sasa 2001, 2009)

If a feature [round] is associated with a vowel, the same [round] feature is linked to all of the vowels in a word.

The markedness constraint in (8) is fully satisfied when all of the vowels in a word share the same [round] feature. (8) assigns a violation to a vowel that does not share the same roundness feature with other vowels in a word.

Finally, the general faithfulness constraint in (9) checks the Input-Output roundness identity of any vowels in the word.

(9) **IDENT [ROUND]** (McCarthy and Prince 1995)

Correspondent input and output segments have the same specification for the feature [round].

As mentioned, both HG and standard OT are constraint-based. In Standard OT, constraints are ranked, and the violations of higher-ranked constraints are more 'fatal' than those of lower-ranked constraints. The tableau in (10) presents the analysis of roundness harmony in Standard OT, and in (10), the violation of SPREAD [ROUND] is more importany than that of IDENT [ROUND] because these constraints are ranked as SPREAD [ROUND] >> IDENT [ROUND].

(10) Roundness Harmony: In Standard OT (where the *ranking* is SPREAD >> IDENT)

/olo-xa/	IDENT σ1 [ROUND]	SPREAD [ROUND]	IDENT [ROUND]
☞ a) olo-xo |// [round]			*
b) olo-xa |/ [round]		*!	
c) ala-xa	*!		*

In (10), candidate (10c) violates the highest-ranked constraint since the vowel in the first syllable is not faithful to its input correspondent in roundness. Candidate (10b) incurs one violation for the spreading constraint because the [round] feature of the first vowel is not associated with the vowel in the suffix. The actual form, (10a), does violate IDENT [ROUND] but this violation is not as serious as the SPREAD violation because IDENT [ROUND] is ranked lower than the spreading constraint.

As seen in (10), in Standard OT, the candidate with the violation of the lower-ranked constraint is selected as the winner. In (10), it is the *ranking* of the constraints, IDENT σ1 and IDENT [ROUND], that determines the winner. The violations of the higher-ranked constraints are more fatal, and the candidates with the violations of the higher-ranked constraints are excluded from the competition. In accounting for Yakut roundness harmony, the constraints in (7) through (9) are ranked as IDENT σ1, SPREAD [ROUND]>> IDENT [ROUND]. (10) shows that this ranking accounts for roundness harmony.

In HG, on the other hand, constraints are not ranked. Instead, constraints are weighted, and in determining the winner, harmonic score is calculated. (11) below presents the analysis of roundness harmony in HG.

(11) Roundness Harmony: In Harmonic Grammar with *Weighted* Constraints

/olo-xa/	IDENT σ1 [ROUND] 3	SPREAD [ROUND] 2.5	IDENT [ROUND] 0.25	Harmonic Score
☞ a) olo-xo |// [round]			1	-0.25
b) olo-xa |/ [round]		1		-2.5
c) ala-xa	1		1	-3.25

In (11), the weight of a constraint is given below each constraint. For example, the

weight of IDENT σ1 is 3, and candidate (11c) receives the score of -3 for the violation of this constraint (-3x1). The harmonic score of candidate (11b) is -2.5 because this candidate violates SPREAD [ROUND] once (-2.5x1). The most harmonic form is (11a) since the harmonic score of this candidate, which is -0.25x1= -0.25, is smaller than that of (11b) and (11c).

According to Pater (2016), the number of each weight (in (11), 3 for IDENT σ1, 1 for SPREAD [ROUND], and 0.25 for IDENT [ROUND]) can be arbitrary. Thus, the weight in (11) could be 100 for IDENT σ1 and 50 for IDENT [ROUND]. The only principle that governs weight assignment is that weight needs to be assigned in such a way that the harmonic score of the actual form is smaller (in the absolute value) than those of losing candidates. In (11) the weight of SPREAD [ROUND] needs to be bigger than that of IDENT [ROUND] (ω(SPREAD [ROUND] >> ω(IDENT [ROUND]), in which the symbol ω reads as 'the weight of') because if the weight of SPREAD [ROUND] were smaller than that of IDENT [ROUND], an unattested form would be selected as optimal. This is illustrated in (12).

(12) Reversed Weight: ω(IDENT [ROUND]) >>ω(SPREAD [ROUND]) Selects an Unattested Form.

/olo-xa/	IDENT σ1 [ROUND] 3	SPREAD [ROUND] 1	IDENT [ROUND] 2	Harmonic Score
☹ a) olo-xo |// [round]			1	-2
b) olo-xa |/ [round]		1		-1
c) ala-xa	1		1	-5

In (12), the weighing relation between SPREAD [ROUND] and IDENT [ROUND] is reversed, and as a result, the harmonic score of (12a), the actual form, is bigger than that of (12b), an unattested form. Thus, the weighting relation, ω(IDENT [ROUND]) >>ω(SPREAD [ROUND]), selects the wrong form, and this suggests that the weight of SPREAD [ROUND] needs to be bigger than that of IDENT [ROUND].

Thus far, the basic roundness harmony pattern of Yakut has been analyzed to demonstrate the basic mechanism of HG. In the next section, a more complex harmony pattern is discussed to examine whether HG is successful in presenting a full analysis of Yakut vowel harmony. Two more constraints need to be added to account for the restriction of roundness harmony, and it is demonstrated that HG accounts for the restriction on the roundness harmony with these two added constraints along with those introduced in this section.

3.2. Yakut Roundness Harmony: A Full Analysis

It has been demonstrated that HG successfully accounts for the basic Yakut roundness harmony pattern with the weighted constraints in (7) through (9). However, as shown in (13), the mechanism proposed thus far fails to account for the case in which roundness harmony is restricted.

(13) Restricted Roundness Harmony; Roundness Harmony Enforced

/tynnyk-ler/	IDENT σ1 [ROUND] 3	SPREAD [ROUND] 2.5	IDENT [ROUND] 0.25	Harmonic Score
☹ a) tynnyk-ler | / [round]		1		-2.5
b) tynnyk-lœr | / / [round]			1	-0.25
c) tinnik-ler			2	-0.5

In (13), the actual form is (13a), in which the [round] feature associated with the high vowels is not linked to the non-high vowel; as mentioned, non-high vowels do not participate in roundness harmony when they are preceded by high round vowels. However, this candidate loses to (13b), in which the same [round] feature is associated both with the high vowels and with the non-high vowel. As demonstrated in (11) and in (12), the weighting relation between SPREAD [ROUND] and IDENT [ROUND] cannot be changed, and this suggests that a new mechanism needs to be added to the grammar to account for the restriction of the Yakut roundness harmony.

To present a full analysis of Yakut roundness harmony (and thus, to account for the restriction of the harmony), the following two constraints need to be included in the grammar.

(14) *œ/o (cf. Kaun 1995)

Non-high round vowels are prohibited.

(15) **UNIFORMITY ROUND** (Kaun 1995)

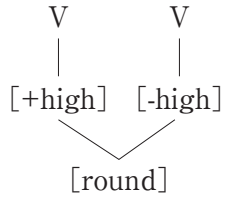
[Round] may not be multiply linked to slots if slots are different in height.

The occurrence of non-high vowels is restricted in Yakut, and the markedness constraint in (14) prohibits non-high round vowels in the output. At the same time, however, non-high round vowels are not completely banned, and as seen in (6), non-high vowels participate in roundness harmony when they are preceded by round vowels of the same height. The markedness constraint in (15) prohibits the linking

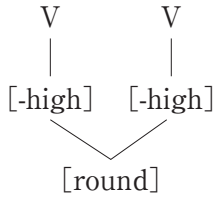
shown in (16a), but the configuration in (16b) does not violate this constraint.

(16) Violation and Satisfaction of UNIFORMITY ROUND (V stands for a vowel)

(16a)



(16b)



UNIFORMITY [ROUND] * violated ✓ satisfied

In (16a), the same [round] feature is multiply linked to two vowels of different height; the preceding vowel is [+high], such as [y], for example, and the following vowel is [-high], such as [œ], for example. This configuration violates UNIFORMITY ROUND since the same [round] feature is linked to two vowels of different height. (16b) represents the configuration of [o-o], for example, and this configuration does not violate UNIFORMITY [ROUND]; in (16b), the same [round] feature is linked to two vowels but these two vowels are both [-high].

The evaluation with (14) and (15), along with the constraints from the previous section, is presented in (17). In (17), the candidate *[tinnik-ler] is omitted, and this candidate loses because of IDENT [ROUND] σ1 weighted as 3, which is not included in the tableau due to the space limitations.

(17) Roundness Harmony Restricted

/tynnyk-lœr/	SPREAD [ROUND] 2.5	UNIFORMITY [ROUND] 2	*o/œ 1.5	IDENT [ROUND] 0.25	Harmonic Score
☞ a) tynnyk-ler | / [round]	1			1	-2.75
b) tynnyk-lœr | / / [round]		1	1		-3.5

In (17), a *gang-up effect* is observed; a gang-up effect refers to the situation in which the assigned score from the violation(s) of a heavier weighted constraint (in this case, the violation of SPREAD [ROUND]) is reversed by the accumulation of the scores from less heavily weighted constraints. In (17), (17a) violates SPREAD [ROUND], which is more heavily weighted than UNIFORMITY [ROUND] and *o/œ, but this violation, or the score from this violation, is overturned by the violations of less weighted constraints by

(17b). As a result, (17a) is judged to be more harmonic than (17b), and selected as the winner in (17).

Finally, the analysis in (18) shows that the mechanism in (17) successfully accounts for the case in which non-high vowels participate in roundness harmony.

(18) Roundness Harmony Enforced

/oʏo-lar/	SPREAD [ROUND] 2.5	UNIFORMITY [ROUND] 2	*o/œ 1.5	IDENT [ROUND] 0.25	Harmonic Score
☞ a) oʏo-lor/ | / / [round]			3	1	-4.75
b) oʏo-lar |/ [round]	1		2		-5.5

In (18a), the same roundness feature is associated with all of the vowels, and SPREAD [ROUND] is satisfied. (18a) does not violate UNIFORMITY [ROUND] because all of the vowels in this form are specified as the same height specification, i.e. [-high]. (18a) is worse under *o/œ and IDENT [ROUND] but the penalties from these constrains do not overturn the penalty of (18b) from SPREAD [ROUND]. As a result, (18a) is judged to be the more harmonic, and thus, selected as the winner in (18).

(17) and (18) show that HG with weighted constraints is successful in accounting for the roundness harmony patterns attested in Yakut. One advantage of the analysis with HG is that it is not necessary to assume an additional constraint that either enforces spreading or multiple linking of a specific vowel (such as EXTEND [ROUND] IF [-HIGH] (Kaun 1995), or that directly prohibits a certain sequence of vowels, such as *HIGH-LOW [ROUND] (Sasa 2001, 2009)). In other words, more general constraints, when properly weighed, seem to be sufficient to account for the attested cases in Yakut. It goes without saying that more data from other languages need to be examined to reach a definitive conclusion, but the analyses presented thus far will function as a starting point to explore the question of whether HG with weighted constraints can be applied to the analyses of various vowel harmony patterns attested in many other languages.

4. Discussion and Conclusions

In this article, it has been demonstrated that HG is applicable to vowel harmony. As seen in Section 3, HG with weighted constraints is successful in accounting for the attested roundness harmony patterns of Yakut. The basic or unrestricted harmony is accounted for by SPREAD [ROUND] being weighted heavier than IDENT [ROUND], and the restricted occurrence of non-high round vowels is attributed to the gang up effect whereby the penalty of the actual form is reversed by the accumulated violations or

penalties of the less heavily weighted constraints of the losing candidates.

The HG analysis of Yakut roundness harmony presented thus far is successful, but there remain some empirical questions. These questions include, first, whether the proposed HG analysis accounts for the more complicated patterns in Yakut shown in (19).

(19) More Affixed Forms (Krueger 1962: 104-105)

Root	1st.pl.poss.	1st.pl.poss.dat
a) tynnyk- 'window'	tynnyk-pyt	tynnyk-pyt-yger (*tynnyk-pyt-ygœr)
b) kœtœr- 'bird'	kœtœr-pyt	kœtœr-pyt-yger (*kœtœr-pyt-ygœr)
c) ohox- 'stove'	ohox-put	ohox-put-ugar (*ohox-put-ugor)

Morphologically, Yakut is an agglutinating language, and it is possible for a root to take more than two suffixes. In (19), roots are followed by two suffixes: the first person (1st.) plural (pl.) possessive (poss.) and the dative (dat.) suffix. Even when a root takes more than two suffixes, the restriction remains the same, i.e. non-high round vowels are not observed after high round vowels, and the remaining question to be investigated is whether the system or the grammar proposed in this article for Yakut accounts for the more complex data as in (19).

Another empirical question is related to a more general theoretical question. One criticism against HG, according to Pater (2016) is that HG may overgenerate linguistic patterns, and it may yield unattested linguistic patterns. When it comes to roundness harmony, to the best of my knowledge, there are three patterns with respect to the occurrence of non-high round vowels: i) non-high round vowels do not follow high round vowels (Yakut); ii) non-high vowels do not precede high round vowels (Kachin Khakass (Korn 1969); and iii) non-high vowels do not follow any round vowels (Turkish (Clements and Sezer 1982)). For HG to be a viable phonological theory, it is necessary to examine if HG yields the above-mentioned three patterns but no other unattested types.

There are both theoretical and empirical issues to be further investigated. Still, it can be concluded that the HG approach to vowel harmony is worth investigating, and it is worth investigating whether HG with differently weighted constraints can account for the full typology of roundness harmony. It is to be hoped that this small squib will serve as a starting point to the bigger empirical and theoretical investigations of the HG treatments of vowel harmony.

Works Cited

Beckman, Jill. “Positional Faithfulness, Positional Neutralization, and Shona Vowel Harmony.” *Phonology* 14, 1997, pp. 1-46.

Beckman, Jill. *Positional Faithfulness*. Ph.D. dissertation, University of Massachusetts, Amherst, 1998.

Clements, George N. and Engin Sezer. “Vowel and Consonant Disharmony in Turkish.” *The Structure of Phonological Representations*, Vol. II, 1982, pp. 213-255.

Ebata, Fuyuki. *Saha-go Bunpou* (*Sakha Grammar*). 2021.

Hayes, Bruce and Londe Zsuzsa. “Stochastic Phonological Knowledge: the Case of Hungarian Vowel Harmony.” *Phonology* 23, 2007, pp. 59-104.

Kaun, Abigail. *The Typology of Rounding Harmony: an Optimality Theoretic Approach*. Ph.D. dissertation, University of California, Los Angeles, 1995.

Korn, David. “Types of Labial Vowel Harmony in the Turkic Languages.” *Anthropological linguistics* 11, 1969, pp. 98-106.

Krueger, John. *Yakut Manual*, 1962.

McCarthy, John and Alan Prince. “Faithfulness and Reduplicative Identity.” *Papers in Optimality Theory*, 1995, pp. 249-384.

Padgett, Jaye. “Partial Class Behavior and Nasal Place Assimilation.” Proceedings of Southwest Optimality Theory Workshop, 1997, pp. 1-40.

Padgett, Jaye. “Feature Class in Phonology.” *Language* 78, 2002, pp. 81-110.

Pater, Joe. “Weighted Constraints in Generative Linguistics.” *Cognitive science* 33, 2009, pp. 999-1035.

Pater, Joe. “Universal Grammar with Weighted Constraints.” *Harmonic Grammar and Harmonic Serialism*, 2016, pp. 1-46.

Sasa, Tomomasa. “Yakut Vowel harmony: an Optimality Theory Account.” *Turkic Languages* 5, 2001, pp. 270-287.

Sasa, Tomomasa. *Treatment of Vowel Harmony in Optimality Theory*. Ph.D. dissertation, The University of Iowa, 2009.