Votic vowel harmony in Substance Free Logical Phonology *

Marjorie Leduc, Charles Reiss & Veno Volenec
Concordia University

1. Theoretical background

We provide an analysis of Votic vowel harmony to illustrate an approach we call Substance Free Logical Phonology. We assume that an analysis cannot be undertaken in a theoretical vacuum, that there is no 'raw' data (Hammarberg, 1981). In this light, we expect that pretheoretically labelled phenomena like 'Votic vowel harmony' may turn out to be the result of several distinct processes stated within a given theory. Such a conclusion follows from the ontological commitments of a theory—its representational and computational apparatus—and how clever the analysts are in applying those resources.

We assume an innate set of binary phonological features which are transduced in complex, but systematic ways between the output of the grammar and the performance systems involved in speech production and perception (see Volenec and Reiss, 2018, for discussion). The model is substance-free in the sense that the motor and perceptual correlates of a feature are not accessible to the phonological computational system. A process turning +LATERAL to −LATERAL before a +ROUND vowel has the same status as one turning +HIGH to −HIGH before a +NASAL segment from the perspective of the computational system, regardless of the relative phonetic plausibility of the two processes, their relative typological rareness, their apparent presence in 'child speech', or any other factors discussed in the literature under the rubric of *markedness*. In fact, 'substance-free' can be safely understood as 'markedness-free'. The two processes above are represented differently because they are formulated with different features (and coefficients), but for the grammar, the features are arbitrary symbols, as discussed by Hale and Reiss (2008) and related work.

We use the name 'Logical Phonology' in order to reiterate the substance free nature of phonology as we conceive it, and also because we think that much of phonology can be done using very simple mathematico-logical notions such as aspects of basic set theory. The toolkit we use here is presented in more detail in Bale and Reiss (2018), and it provides us with a means of defining the crucial notion 'possible phonological rule'.

In this brief discussion we will abstract away from many important issues, such as the structure of apparent contour segments, the relevance of syllable structure, and much more. Most glaringly, we will not be able to explore how we view the determination of rule environments and the nature of locality. Chapter 8 in the current volume by Andrew

*This chapter draws on various other work written and presented by all three authors, along with several co-authors, to whom we are grateful. These include Alan Bale, Maxime Papillon and David Ta-Chun Shen.

Nevins adopts many of the same ideas we assume here with respect to locality, but differs in crucial details, some of which are presented elsewhere (Mailhot and Reiss, 2007; Shen, 2016). Our narrow focus here will be on structural changes, how rules change their targets. Even more narrowly, but appropriate in the context of vowel harmony, we examine only changes that occur *inside* of segments, so we exclude phenomena like segment insertion, deletion and metathesis. We propose that deletion of features, via set subtraction, and insertion of features, via unification, are the only two operations needed to express the changes wrought by phonological rules inside of target segments. Since Votic harmony can be modelled as purely feature-filling, we will only make use of unification in this chapter.

1.1 Segments and natural classes

One of the core notions of Logical Phonology (LP) is the view of segments as sets of (valued) features. The sets corresponding to the segments /m/ and /n/ are (partially) given in (1):

(1) Segments as sets of valued features

a. /m/ = $\{+\text{NAS}, +\text{LAB}, -\text{COR}, -\text{CONT}, \dots\}$

b. /n/ = $\{+\text{NAS}, -\text{LAB}, +\text{COR}, -\text{CONT}, \dots\}$

The ellipsis '...' refers to all the other features for which a segment has values.

With this view of segments, we take natural classes to be sets of segments, that is, sets of sets of valued features. If the set of segments occurring in a language is Σ, then it is not the case that any arbitrary subset of Σ, *S*, constitutes a natural class. In LP we define natural classes as follows:

(2) Definition: If $S = \{s_1, s_2 ... s_k\}$ is a subset of the segments occurring in a language *L*, and $Q = (s_1 \cap s_2 \cap \ldots \cap s_k)$ is the (generalized) intersection of *S*, then the **smallest natural class** *N* in *L* containing the members of *S* is the set of all segments that are supersets of *Q*. So, $N = \{x : x \supseteq Q\}$.[1]

N will always be a superset of *S* (potentially equal to *S*). It thus follows that *N* may very well contain members that are not in *S*. For example, consider a language with *i,e,a,o,u*. If a rule targets the members of *S*= {*i,o*} then it must (intensionally) target all members of *N*= {*i,e,o,u*}. This is because all four of those vowels are supersets of the features in the intersection of *i* and *o*. Assuming that just HI, LO, BK and RD are relevant, *i* ∩ *o* = {-Lo}. No rule can target just *i* and *o*; conversely, an apparent rule targeting only *i* and *o* must correspond to separate rules (see Bale and Reiss, 2018, for discussion). This explicit definition of natural classes is thus part of an explicit definition of 'possible phonological rule'. This position is implicit in much of the literature, but it is also clear that it is not

[1]We've illustrated here using normal intersection, but by using generalized intersection we can account for the case where *S* (and *N*) has a single member.

universally adopted given widespread discussion of the possibility that rules sometimes might *not* refer to natural classes (e.g. Mielke, 2008). In LP such a claim makes no sense.

Note that natural class is for us a *phonological* notion, not a directly phonetic one. This is consistent, at least implicitly, with most of the literature, including *SPE* (Chomsky and Halle, 1968). Features have phonetic correlates, but the feature inventory used by phonologists is chosen to capture sets of segments that act the same *phonologically*.

Ignoring the ellipses in (1), the smallest natural class containing /m/ and /n/ is this:

(3) $\{x : x \supseteq \{+\text{N}\textsc{as}, -\text{C}\textsc{ont}\}\}$

Thus, the smallest natural class containing /m/ and /n/ is the set of segments that are specified, that have as members, +NASAL and −CONTINUANT. Because of the unwieldy notation in (3), we use square brackets to represent natural classes. The natural class represented in (3) will be denoted as in (4):

(4) Natural class notation: $[+\text{N}\textsc{as}, -\text{C}\textsc{ont}]$

So, the target of a rule and the environment of a rule will be denoted with the square bracket notation, but the structural change, which does not refer to a set of segments, will be denoted with normal set brackets, as explained in Bale and Reiss (2018).

We have defined segments as sets of valued features, but in LP, we assume that not every set of valued features can be a segment. We assume that segments are *consistent*: a segment cannot have as members opposite valued features. For example, if a segment is specified +BACK, then it cannot be specified −BACK. We do not assume, however, that segments must be *complete*: it is possible for a segment to be unspecified for either value of BACK. In other words, we accept *underspecification*.

1.2 Unification

Viewing segments and natural classes as sets allows for the use of various set theoretical operations in rules, replacing the all-purpose '→' of traditional phonological rules. In this paper, we focus on *unification*, an operation defined in (5), using regular set union, ∪:[2]

(5) If A and B are sets, then $A \sqcup B = A \cup B$ if $A \cup B$ is consistent. Otherwise, $A \sqcup B$ is undefined. (Bale and Reiss (2018): 567)

Because its output may be undefined, unification is called a 'partial' operation, in contrast to regular set union which always yields an output for any two input sets: $A \cup B$ is always defined. To illustrate, consider four sets of features and the result of various unifications:

(6) Four sets of features

$A = \{+\text{H}\textsc{i}, -\text{R}\textsc{d}\}$

[2]The union of two sets A and B is the set C that contains all elements that are in A, or in B (or in both). If $A = \{x, y\}$ and $B = \{x, z\}$, then $A \cup B = \{x, y, z\}$.

$B = \{+\textsc{Hi}, -\textsc{Bk}\}$

$C = \{-\textsc{Lo}, +\textsc{Rd}\}$

$D = \{+\textsc{Hi}\}$

(7) Result of unification

$A \sqcup B = \{+\textsc{Hi}, -\textsc{Rd}, -\textsc{Bk}\}$

$A \sqcup C$ is undefined because $A \cup C$ is not consistent

$B \sqcup C = \{+\textsc{Hi}, +\textsc{Rd}, -\textsc{Bk}, -\textsc{Lo}\}$

$A \sqcup D = \{+\textsc{Hi}, -\textsc{Rd}\}$

In LP, rules map strings of segments to strings of segments (in the simplest case). If a rule contains a unification operator, then whenever a unification is undefined, or ‘fails’, the output string is identical to the input string. Thus, unification failure leads to one kind of vacuous rule application. Another kind of vacuous application results from cases like $A \sqcup D$ in (7), when a target segment unifies with a subset of itself. We will use these two kinds of vacuous application to develop a feature-filling analysis of Votic vowel harmony. Feature-changing rules require another basic operation, set subtraction, which does not appear to play a role in Votic harmony.

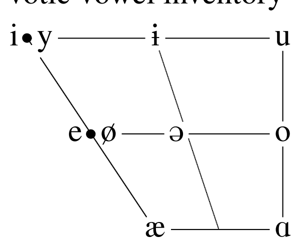
2. Votic language

2.1 Surface inventory

Votic is a Finnic language from Ingria, in northern Russia. In 2011, it was considered to be nearly extinct, with only a few speakers remaining (Blumenfeld and Toivonen (2016) citing Heinsoo and Kuusk (2011)). Our data comes from Ariste (1968).

Length contrasts are not relevant to harmony behavior in Votic. Ignoring length, the vowel inventory is given in (8).

(8) Votic vowel inventory



For our purposes, the features HIGH, LOW, BACK, ROUND can characterize the inventory. The +HIGH, −LOW, +BACK, −ROUND vowel /ɨ/ occurs only in Russian loanwords, and it does not participate at all in vowel harmony in Ariste’s description.

2.2 Basic BACK harmony facts

As illustrated in Table 1, Votic has BACK harmony, with each suffix vowel agreeing with the preceding (or last root) vowel with respect to this feature.

Table 1: Votic vowel harmony

−BACK V in root		+BACK V in root	
a.[vævy-æ]	'son-in-law.PART.'	[sɑvvə-ɑ]	'clay.PART.'
b.[ø-heː]	'night.ILLAT.'	[so-həː]	'marsh.ILLAT.'
c.[væsy-nny]	'tired.PAST.ACT.'	[ɑrvɑ-nnu]	'guessed.PAST.ACT.'
d. [sətɑmehe-nnæ]	'soldier, warrior.ESS.'	[lenno-lʲlʲɑ]	'tree.ADDESS.PL'

The forms in row (d) show mixed roots, with harmony determined by the BACK value of the vowel closest to the suffix.

The vowel /i/ in roots or non-final suffixes, does not trigger harmony in suffixes. The forms in Table 2 show that the BACK value in the suffix vowel is determined by the vowel preceding (one or more occurrences of) the vowel /i/:

Table 2: Transparency of /i/

−BACK V IN ROOT		+BACK V IN ROOT	
a. [tšæs-**i**-næː]	'hand.COMIT. II.PL'	[pəlʲv-**i**-nɑː]	'knee.COMIT. II.PL.'
b. [pehm**i**ː-seː]	'soft.ILLAT.PL'	[vətt**i**m-**i**ː-səː]	'key.ILLAT.PL'

Even sequences of two /i/'s show this transparent behavior: in the form *vəttim-iː-səː* the vowel of the suffix [-səː] 'looks' all the way back to the initial ə to harmonize as [+BACK], skipping two instances of /i/.

When occurring in a suffix, the vowel /i/ does not participate in harmonic alternations with other vowels, as seen in Table 3:

Table 3: No alternation involving /i/

−BACK V IN ROOT		+BACK V IN ROOT	
[ylepæ-ssi]	'chief.TRANSL.'	[ɑntə-ssi]	'as forgiveness.TRANSL.'
[teh-tiː]	'it was done, made'	[tulʲ-tiː]	'one had come'

The /i/ in suffixes does not alternate, and the vowel surfaces after roots ending with either front or back vowels. Further examples of /i/ remaining unchanged in both front and back environments can be seen in the suffixes /-ikko/ and /-nikkɑː/ in Table 4:

Table 4: non-alternating suffixes

−BACK V IN ROOT		+BACK V IN ROOT	
[tø-kɑː]	'work.COMIT.'	[jɑlʲgɑː-kɑː]	'foot.COMIT.'
[tyttær-ikko]	'girl'	[kot-ikko]	'little bag'
[seipæ-ddeː]	'stake, pole.GEN.PL'	[pu-ddeː]	'tree.GEN.PL.'
[øː-nikkɑː]	'night lodger'	[pulʲmɑ-nikkɑː]	'wedding guest'

These forms show important details of Votic vowel distribution concerning the existence of suffixes with vowels besides /i/ that do not alternate. The comitative suffix has a non-alternating vowel [ɑː], and the genitive suffix has a non-alternating vowel [eː]. However, we have already seen suffixes where [ɑː] alternates with [æː], and where [əː] alternates with [eː] as in Table 2. Further, the final vowel of the suffix /-ikko/ reflects another detail about Votic that must be borne in mind: despite the existence of minimal pairs like *soː* 'marsh' vs. *søː* 'eat', there is no BACK harmony alternation involving the vowels /ø/ and /o/. In fact, the vowel /ø/ never appears in suffixes. This observation tells us that the mere existence of a 'contrastive pair' in surface forms is not a sufficient condition for predicting the existence of harmony alternations.[3] The irrelevance of contrast is consistent with the tenets of Logical Phonology. The notion of contrast is tied to the communicative use of language. However LP treats phonology as pure computation with no access to notions like ambiguity or neutralization. Phonologists use contrast, as seen in minimal pairs, as heuristics for getting at the contents of a language's lexicon, but the phonology itself is indifferent to contrasts and minimal pairs (Reiss, 2017), as Votic clearly demonstrates.

2.3 Roots with just /i/

We have noted that /i/ does not alternate with other vowels via harmony, and that one or more /i/ is 'skipped' by the process that harmonizes a suffix with the first preceding BACK value. It is important to mention that Votic has some roots containing no vowels other than /i/, such as *siːli* 'hedgehog'. Suffixes with vowels that harmonize do attach to these roots, and they surface as −BACK, as in (9).

[3]Kiparsky and Pajusalu (2003, p. 219) claim that "A vowel fails to undergo harmony when its harmonic counterpart is prohibited, either in the inventory of phonemes (context-free neutralization) or by a distributional restriction (positional neutralization), e.g., the absence of non-initial *ɨ* in Southeastern Estonian." Kimper (2011, p. 46) demonstrates that the first part of this claim is false, that harmony is not necessarily 'structure-preserving' and can in fact introduce allophonic vowels. The second part of the claim could potentially explain the failure of harmony between the harmonic pair /ø/ and /o/ in Votic, since the former vowel appears only in initial syllables. However, the explanation fails in general, since *some* cases of *e* alternate with *ə*, but others don't. Our position is that surface contrasts cannot be the locus of explanation—some cases of *e* derive from /E/ and participate in harmony, whereas others derive from /e/ and do not. Our approach is explicitly *not* 'surface oriented'.

(9) 'hedgehog.PART.'
[siːli-æ]

We have seen in Table 1, row (a) that the vowel in this suffix harmonizes elsewhere and surfaces as −BACK or +BACK depending on the root it is attached to. We need to decide if the −BACK suffix vowel here is a result of a default assignment, or somehow a copy of a value on one of the underlying /i/ vowels.

To review, the Votic data presents a few challenges. First we have to account for surface vowel pairs like [e] and [ə] whose members sometimes do and sometimes don't alternate via harmony. Second, we have to account for surface vowels that act as triggers but don't participate in alternations (as targets), like [ø] and [o], despite being harmonic 'twins', differing only with respect to the harmonizing feature BACK. Third, we have to account for the neutral behavior of /i/, which is never a target, and is transparent and not a trigger in roots containing additional vowels, but is perhaps a trigger in roots with no other vowels.

In the following section, we combine principles of Logical Phonology sketched so far with an informal version of the SEARCH and COPY processes sketched in Mailhot and Reiss (2007) to develop a simple account of the challenges presented by Votic BACK harmony.

3. Analysis

Our analysis concerns the featural make-up of Votic vowels, and the nature of the rules that map strings containing these underlying vowels to their surface forms.

3.1 Vowel representations

We posit that all root vowels in Votic are fully specified in accordance with their surface representations. Since every surface vowel can occur in roots, this yields ten fully specified vowels. The set representations for four of these are given in (10).

(10) Some of the fully specified vowels of Votic

$$\text{/e/: } \left\{ \begin{matrix} -\text{HIGH} \\ -\text{LOW} \\ -\text{ROUND} \\ -\text{BACK} \end{matrix} \right\} \quad \text{/ə/: } \left\{ \begin{matrix} -\text{HIGH} \\ -\text{LOW} \\ -\text{ROUND} \\ +\text{BACK} \end{matrix} \right\} \quad \text{/æ/: } \left\{ \begin{matrix} -\text{HIGH} \\ +\text{LOW} \\ -\text{ROUND} \\ -\text{BACK} \end{matrix} \right\} \quad \text{/ɑ/: } \left\{ \begin{matrix} -\text{HIGH} \\ +\text{LOW} \\ -\text{ROUND} \\ +\text{BACK} \end{matrix} \right\}$$

Other fully specified vowels of Votic include the mid round /o/ and /ø/, as well as four high vowels, fully specified versions of /i/, /y/, /ɨ/ and /u/. In addition to being found in roots, these fully specified vowels are also present in non-alternating syllables of suffixes.

We will assume that the lexicon of Votic contains three additional vowels underspecified for BACK:

(11) Underspecified vowels of Votic

$$/U/: \left\{\begin{matrix} +\textsc{High} \\ -\textsc{Low} \\ +\textsc{Round} \end{matrix}\right\} \quad /E/: \left\{\begin{matrix} -\textsc{High} \\ -\textsc{Low} \\ -\textsc{Round} \end{matrix}\right\} \quad /A/: \left\{\begin{matrix} -\textsc{High} \\ +\textsc{Low} \\ -\textsc{Round} \end{matrix}\right\}$$

The high, round vowel /U/ is the underlying vowel in [y] ∼ [u] alternations; /E/ underlies the [e] ∼ [ə] alternations; and /A/ underlies the [æ] ∼ [ɑ] alternations.

These underspecified vowels acquire a BACK value from the first preceding vowel that is not /i/. The vowel that transmits its BACK value can be in either root or suffix—our rules make no reference to morphological structure. We also assume that these underspecified vowels do not acquire a −BACK value when they are attached to roots containing just /i/. That fully specified vowel never transmits its value. Because LP does not appeal to notions of markedness or contrastiveness, we must account for the failure of /i/ to transmit its feature to the nature of the rule system, which we now turn to.

4. The rules

4.1 A first attempt

Because we derive vowel harmony alternations from underlyingly underspecified vowels, the rules we invoke will be feature-filling rules containing the unification operator, following Bale et al. (2014); Bale and Reiss (2018) and other recent work. We will invoke, without justification here, an informal combination of the unification model with the SEARCH and COPY approach to long-distance interactions, inspired by Shen (2016). A further expository simplification will be to refer to the valued feature +SYLLABIC to characterize the natural class of vowels, but see Bale et al. (2019) for why this is not necessary. Using the square bracket notation for natural classes introduced in (4), here's a first attempt at a harmony rule for Votic:

(12) BACK harmony (first try):
$[+\textsc{Syl}] \sqcup \{\alpha\textsc{Bk}\}$ / when the first vowel to the left is in $[\alpha\textsc{Bk}]$

Before we show what's wrong with this, let's clarify some details of the rule format. Note that the target of the rule is characterized as the natural class [+SYLLABIC]. This is the set of all vowels. Crucially, we are not able to target only the underspecified segments,[4] which are the ones that we know are affected by the rule. It looks like we have made the rule overly general since it takes as input a string of segments which it maps to an output string of segments by 'trying' to unify each vowel in the input string with the set containing the αBACK value of the preceding vowel.

Sometimes, this 'wide net' that we have cast won't matter, for example, if we unify a vowel that is underlyingly specified −BACK with {−BACK} copied from the preceding

[4]This follows from the definition of natural classes in (2). See Bale and Reiss (2018) for discussion.

vowel. Unification applies, but vacuously.

What happens when the rule tries to unify, say, a vowel that is specified $-$BACK with $\{+$BACK$\}$ copied from the preceding vowel? This is where the character of unification as a partial operation comes into play. Because the union of the two sets is inconsistent, unification fails, and as explained above, our rule semantics leaves the input string unchanged—the rule applies vacuously.[5] Notice that we have now explained the fact that /i/, and the other fully specified vowels, are not affected by harmony. Either they unify with a set containing a BACK value that they already contain, or else unification fails. An underlying /i/ is not different from an underlying /ø/ or /o/ in this respect.

The only time such a rule will apply non-vacuously is when the target segment is underspecified in the input string, and the corresponding segment in the output is the result of the unification of that input segment with a set containing the αBACK specification copied from a preceding vowel.

4.2 The problem of /i/

The problem with rule (12) is that it treats all trigger vowels alike. The vowel /i/ is different in two ways that concern us now. First, it does not trigger harmony, and second it is transparent, allowing preceding vowels to trigger harmony.

Let's deal with the second problem first. The solution lies in the SEARCH approach to phonological rules developed in Mailhot and Reiss (2007) and Shen (2016).[6] In brief, the SEARCH algorithms allow rules to proceed through a string and find the first token of a segment satisfying some property. If that property is 'don't be /i/', the rule will keep searching until it finds a vowel other than /i/. Note that, once again, we achieve a desired effect by building it into the formal system, rather than by appealing to markedness or contrast.

This solution to the second problem, however, highlights our first problem, the fact that /i/ is not a trigger of harmony. Recall that LP demands that the triggers and environments of rules be defined by natural classes. Now 'don't be /i/' or 'any vowel except /i/' is not a natural class, since there is no set of features P such that every Votic vowel except /i/ is a superset of P.

How do we know that there is no such set of features? LP assumes that phonological representations are built from a universal, innately determined set of features, and as a working hypothesis, we are accepting the existence of the features BACK, ROUND, HIGH, LOW introduced above. Using this set of features, it is impossible to define 'any vowel

---

[5]See Bale and Reiss (2018) for rule semantics, and for discussion of why we never say that rules 'don't apply'—in brief, every rule must have an output if it is to be composed with a subsequent rule (or yield a surfae representation).

[6]Nevins (2010) has a similar approach to phonological locality, developed at around the same time. His system is embedded in a model that makes use of several notions we reject, such as a role for contrast and 'interface conditions' in motivating phonological computation. See his contribution to this volume for more recent views.

except /i/' as a natural class via the generalized intersection operation. Therefore, we are forced to conclude that Votic BACK harmony cannot be the result of a single rule. We need two rules if we want to maintain LP principles. This apparent sacrifice of parsimony (having two rules) is justified by having an explicit theory of natural classes and possible rules.

Recall that /ɨ/ does not participate in harmony in any way, and that /i/ does not either (aside from one situation that we will return to). We can posit one rule for harmony triggered by non-high vowels, and another by high round vowels, as in (13) and (14):

(13) Harmony with Non-High Vowel (NHVH):
$[+\text{SYL}] \sqcup \{\alpha\text{BK}\}$ of the first vowel to the left that is in $[-\text{HI}, \alpha\text{BK}]$

(14) Harmony with High Round Vowel (HRVH):
$[+\text{SYL}] \sqcup \{\alpha\text{BK}\}$ of the first vowel to the left that is in $[+\text{HI}, +\text{RD}, \alpha\text{BK}]$

In addition to these two rules, we assume that, in fact, /i/ never transmits −BACK, even when there are no vowels other than /i/ in a root. Instead we assume a default rule that fills in the value by unifying the set {−BACK} with every vowel. This rule is ordered at the end of the derivation, and the only time it will apply non-vacuously is when there has been no other source to fill in a missing BACK value on an underspecified segment. The rule can be stated in a very general format with no environment needed:

(15) Default −BK (DF):
$[+\text{SYL}] \sqcup \{-\text{BK}\}$

This rule tries to assign −BACK to every vowel. If the rule is ordered at the end of the derivation, then the only vowels lacking a specification for BACK at this point will be those following sequences of /i/'s. In other words, SEARCH for a BACK value by rules (13) and (14) will fail when all the vowels to the left of an underspecified one are tokens of /i/. All other vowels will either have an underlying specification or one derived from the previous rules. In such cases, rule (15) will be vacuous, either because of vacuous unification with −BACK vowels, or because of unification failure with +BACK vowels.

The last element of our analysis is the relative ordering of rules (13) and (14). Consider a hypothetical root /toky/ with an alternating suffix /tA/. If (13) is ordered first, SEARCH skips the high round front /y/ and finds the non-high back /o/, yielding a +BACK suffix vowel: [tokytɑ]. The next rule, (14) will apply vacuously.

In contrast, if rule (14) applies first, underlying /A/ will unify with {−BACK} from the root final /y/, yielding [tokytæ], and (13) would apply vacuously.

A hypothetical root /tyko/ with the order of vowels reversed will yield [tykotɑ] and [tykotæ], respectively, with the same two orderings. As far as we can tell, there are no roots, or possible root-suffix sequences, matching the /toky/ pattern in which an underlying high round vowel occurs to the right of a non-high vowel with a different value for BACK. Therefore, ordering arguments can only be made on the basis of forms that match the /tyko/ pattern, a pattern that seems to reflect two true facts about the Votic lexicon: first, there are no roots in which an underlying /u/ or /y/ follows a non-high vowel; and second, there are no suffixes containing non-alternating /u/ or /y/.

The actual data supports the ordering of rule (13) before rule (14), as shown by the mapping /tyttær-ikko-A/ ⇝ [tyttærikkoɑ] in Table 5. If (14) had been ordered first, the suffix vowel would have received a −BACK, because SEARCH would have proceeded all the way to the /y/ in the initial syllable, yielding ungrammatical *[tyttærikkoæ]. Instead, the suffix vowel is +BACK because rule (13) found the non-high fully specified /o/. We thus have a complete ordering of the rules, yielding the derivations in Table 5:

Table 5: Derivations

UR	‘key.ILLAT.PL’ /vəttim-iː-sEː/	‘tree.ILLAT.’ /pu-hEː/	‘hedgehog.PART’ /siːli-A/	‘girl.PART’ /tyttær-ikko-A/
NHVH	[vəttimiːsəː]	—	—	[tyttærikkoɑ]
HRVH	—	[puhəː]	—	—
DF	—	—	[siːliæ]	—
SR	[vəttimiːsəː]	[puhəː]	[siːliæ]	[tyttærikkoɑ]
comments	αBk spreads from ə	αBk spreads from u	Default −Bk	NHVH bleeds HRVH

The derivations here generate the correct forms using simple representations and rules. Strict adherence to LP principles forces us to recognize that Votic vowel harmony is not a unitary process, but is due to the interaction of three separate rules.[7]

5. Previous analyses

Two recent analyses of Votic made ad hoc assumptions to account for the behavior of /i/. Blumenfeld and Toivonen (2016) worked with a variant of Optimality Theoretic Agreement-By-Correspondence and proposed that /i/ is specified *both* as +BACK and −BACK. They did not elaborate on what this radical claim entails for the phonetic interpretation of feature specification. They chose not to say that /i/ has *neither* specification, because the segment appears to behave like a front vowel in the process of lateral fronting, which we did not discuss here. Given our straightforward treatment of /i/ as a fully-specified front vowel, it is not surprising in the least that it triggers lateral fronting. While it is impossible to refer to a natural class that includes ‘every vowel except /i/’, it is trivial to refer to the natural

[7] We put aside a few problematic forms such as ‘shortened’ allative personal pronouns like [mi-lʲlʲə] ‘I.ALLATIVE’ mentioned by Ariste (p.55). These appear to be lexical exceptions.

class 'just /i/': it's just the set of segments $\{x : x \supseteq \{+\text{HI}, -\text{LO} - \text{BK}, -\text{RD}\}\}$. In Votic, the lateral fronting rule is triggered by this natural class of segments with just one member, /i/.

Hall (2017, 2018) proposed that /i/ does not have a feature for BACK. Instead, he specifies /i/ as CORONAL. The lack of BACK specification is supposed to account for the vowel harmony behavior, and the presence of CORONAL is meant to account for the effect on laterals. This analysis seems gratuitously abstract for a vowel that is always pronounced as [i].

Of course, we have posited three 'abstract' underspecified vowels. However, we were driven to this conclusion by the straightforward distribution of Votic forms. There are non-alternating suffixes with back vowels; there are non-alternating suffixes with front vowels; and there are suffixes that alternate with respect to BACK. The three behaviors require a three-way distinction underlyingly, hence the /e/, /ə/, /E/ contrast, the /æ/, /ɑ/, /A/ contrast, and the /y/, /u/, /U/ contrast.

6. Conclusion

We have used Votic vowel harmony to illustrate the Logical Phonology approach. Important aspects of this model are the acceptance of a set of universal, innate, binary valued features. Segments are consistent, but not necessarily complete sets of these valued features. Natural classes are sets of segments, where the members of a class are defined intensionally as those segments that are a superset of a given set of features. The targets and environment segments of rules in LP are natural classes. This condition allows us to decide whether a pre-theoretically described phenomenon like Votic vowel harmony can be the result of a single rule. Rules are functions from strings to strings, and function composition applies in phonology exactly as in logic and mathematics.

Adherence to basic principles led to the conclusion that we need three separate rules to account for BACK alternations in Votic: a rule that is triggered by non-high vowels (both round and non-round ones); a rule that is triggered by high round vowels (/y/ and /u/); and a default rule that assigns alternating suffix vowels the value $-$BACK in words that contain only the vowel /i/. The first two of these rules are needed to split up the inventory of underlyingly fully specified vowels into two sets (non-high vs. high round), and leave out the so-called neutral /i/ (and the /ɨ/ of recent borrowings). With the vowel inventory split in this way, we formulated two rules using natural classes. The last rule, the default fill-in rule, supports the idea that descriptive terms like 'Votic vowel harmony' should not be accorded too much status: it turns out that in cases where the default rule applies non-vacuously, there is no actual 'harmony' occurring, since the surface suffix vowel is only accidentally agreeing with another vowel.

Our analysis is incomplete in many ways. For example, we did not present a full account of how rules incorporate the SEARCH and COPY procedures, which are perhaps now better understood in terms of SEARCH and UNIFY, as in Shen (2016). Extensions of the methodology demonstrated here is a project for the future.

To appreciate the nature of LP, it is important not only to characterize it in positive terms, but also to reiterate what it does not contain. Our analysis offers explicitly characterized proposals about the nature of phonological representations (e.g., segments are sets) and rules (e.g., rules must be formulated in terms of natural classes; rules contain logical operations like unification). Our LP account does not rely on notions such as contrast or markedness. Instead, we made use of formal properties like the two kinds of vacuous rule application (via vacuous unification and unification failure) to derive a simple account of feature-filling patterns.

Finally, we note that Votic also provides an argument against the notions of surface well-formedness and phonotactics playing a role in grammar. A vowel sequence like [o-e] is 'ill-formed' if the [e] is part of a suffix that shows the [e ∼ ə] alternation, but it is perfectly fine if the [e] is from a non-alternating suffix. As recognized decades ago, the "relation between a phonemic system and the phonetic record . . . is remote and complex" (Chomsky, 1964, p.38). As in syntax, the "essential properties underlie the surface form" (Katz and Bever, 1976, p.12). These ideas are embraced by the approach we have illustrated, much as they were in *SPE* (Chomsky and Halle, 1968).

References

Ariste, Paul. 1968. *A grammar of the Votic language*. Indiana University Press.

Bale, Alan, Maxime Papillon, and Charles Reiss. 2014. Targeting underspecified segments: A formal analysis of feature-changing and feature-filling rules. *Lingua* 148: 240–253.

Bale, Alan and Charles Reiss. 2018. *Phonology: a Formal Introduction*. MIT Press.

Bale, Alan, Charles Reiss, and David Ta-Chun Shen. 2019. Sets, rules and natural classes: {} *vs.* []. *Loquens* To appear.

Blumenfeld, Lev and Ida Toivonen. 2016. A featural paradox in Votic harmony. *Natural Language and Linguistic Theory* 34: 1167–1180.

Chomsky, Noam. 1964. *Current issues in linguistic theory*. Mouton & Company.

Chomsky, Noam and Morris Halle. 1968. *The sound pattern of English*. New York: Harper & Row.

Hale, Mark and Charles Reiss. 2008. *The phonological enterprise*. Oxford: Oxford University Press.

Hall, Daniel Currie. 2017. Locality, neutrality, and contrast: A new resolution to the votic paradox. Paper presented at the 48th meeting of the North East Linguistic Society (NELS), University of Iceland, Reykjavík, Iceland, October 27–29.

Hall, Daniel Currie. 2018. Two ways to be transparent to finnic vowel harmony. Paper presented at the 15th Old World Conference on Phonology, University College London (UCL), London,UK, January 12–14.

Hammarberg, Robert. 1981. The cooked and the raw. *Journal of Information Science* 3(6): 261–267.

Heinsoo, Heinike and Margit Kuusk. 2011. Neo-renaissance and revitalization of votic — who cares? *Journal of Estonian and Finno-Ugric Linguistics JEF* 2: 171–184.

Katz, Jerrold J. and Thomas G. Bever. 1976. The fall and rise of empiricism. In *An integrated theory of linguistic ability*, ed. Thomas G. Bever, Jerrold J. Katz, and D. Terence Langendoen. New York: Thomas Y. Crowell, 11–64.

Kimper, Wendell A. 2011. *Competing triggers: Transparency and opacity in vowel harmony*. University of Massachusetts Amherst Amherst, MA.

Kiparsky, Paul and Karl Pajusalu. 2003. Towards a typology of disharmony. *Linguistic review* 20(2/4): 217–242.

Mailhot, Frédéric and Charles Reiss. 2007. Computing long-distance dependencies in vowel harmony. *Biolinguistics* 1.

Mielke, Jeffrey. 2008. *The emergence of distinctive features*. Oxford: Oxford University Press.

Nevins, Andrew. 2010. Locality in vowel harmony. *Linguistic Inquiry Monograph 55* 18: xii–244.

Reiss, Charles. 2017. Contrast is irrelevant in phonology: A simple account of Russian /v/ as /V/. In *Arguments of substance: Beyond markedness*, ed. Bridget D. Samuels. Amsterdam: John Benjamins, 23–45.

Shen, David Ta-Chun. 2016. *Precedence and Search: Primitive concepts in morpho-phonology*. Taipei: National Taiwan Normal University dissertation.

Volenec, Veno and Charles Reiss. 2018. Cognitive Phonetics: The transduction of distinctive features at the phonology-phonetics interface. *Biolinguistics* 11.