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*Positional faithfulness, positional neutralisation and Shona vowel harmony**

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1 Introduction

The distribution of the feature [high] in Shona verbs is a prototypical example of positional neutralisation accompanied by vowel harmony.[1,2] In languages which exhibit positional neutralisation of vowel contrasts, one or more vowels (generally, the most marked members of the vowel inventory) may occur distinctively in only a small subset of the structural positions available in the language. Outside of these positions, the marked vowels may surface only if they harmonise with a similar vowel in the privileged position. For example, the mid vowels *e* and *o* in Shona verbs are contrastive only in root-initial syllables. These vowels may appear in subsequent syllables only when preceded by a mid vowel in root-initial position. A string of height-harmonic Shona vowels is therefore firmly anchored in the root-initial syllable, as shown in (1):

(1) *Height-harmonic Shona verbs* (Fortune 1955)

pera	'end'	per-e̱ra	'end in'
sona	'sew'	son-e̱ra	'sew for'
vereŋga	'count'	vereŋg-e̱ka	'be numerable'
tonda	'face'	tond-e̱sa	'make to face'
oma	'be dry'	om-e̱sa	'cause to get dry'
seka	'laugh'	sek-e̱re̱ra	'laugh on and on'
ipa	'be evil'	ip-i̱ra	'be evil for'
bvisa	'remove'	bvis-i̱ka	'be easily removed'
bvuma	'agree'	bvum-i̱sa	'make agree'
pinda	'pass'	pind-i̱ri̱ra	'to pass right through'

Low vowels neither trigger nor propagate height harmony; only [+high] *i* and *u* may follow a low vowel, even if the root-initial vowel is mid. This is true of both roots and derived combinations:

(2) *Low vowels block harmony*

charuk-	‘jump over/across’		
ganhur-	‘limit, demarcate’		
katuk-	‘flicker (flame)’		
tandanis-	‘chase’		
kwazis-	‘greet’		
pofomadza	‘blind’	pofomadz-i̲ra	‘blind for’
tarisa	‘look at’	taris-i̲ka	‘easy to look at’
shamba	‘wash’	shamb-i̲sa	‘make wash’
pamha	‘do again’	pamh-i̲sa	‘make do again’
cheyama	‘be twisted’	cheyam-i̲sa	‘make be twisted’

A final restriction on Shona height harmony arises in the interaction of rounding and height harmony. Harmony fails to apply between a root-initial mid front *e* and a subsequent round vowel. Thus, rather than a height-harmonic string of *e…o*, we find disharmonic *e…u*. Harmony applies regularly when the initial vowel is round *o*:

(3) *Height and roundness interactions*

serenuk-	‘water (gums of mouth)’			*serenok-
svetuk-	‘jump’	svetuk-i̲ra	‘jump in’	*svetok-era
pet-	‘fold’	pet-enura	‘unfold’	*pet-enora
pofomadz-	‘blind (TRANS)’	*pofumadz-		
gobor-	‘uproot’	*gobur-		
tonhor-	‘be cold’	*tonhur-		
nonok-	‘dally, delay’	*nonuk-		
bover-	‘collapse inwards’	*bovir		
kobodek-	‘become empty’	*kobudik-		

In this paper, I present a full analysis of Shona height harmony, encompassing the positional neutralisation of height (1), the inertia of low vowels in the system (2), and the rounding restriction on the spreading of [−high] (3). All of these facts arise from the interaction of markedness and faithfulness constraints in Optimality Theory (OT; Prince & Smolensky 1993). The principle innovation here is a set of ROOT-INITIAL FAITHFULNESS CONSTRAINTS, one instantiation of a family of POSITIONAL FAITHFULNESS CONSTRAINTS. Positional faithfulness constraints call for output preservation of underlying contrast in specific psycholinguistically prioritised or perceptually prominent linguistic positions, such as initial syllables, stressed syllables, syllable onsets or root syllables (see McCarthy & Prince 1994b, 1995, Selkirk 1994, Beckman 1995, in preparation, Hume 1996, Lombardi 1996, Smith 1996, and Padgett to appear for recent developments of positional faithfulness in Optimality Theory). Through constraint interaction, positional faithfulness constraints permit a uniform account of a wide range of positional asymmetries in phonology, including positional triggering of phonological processes, positional resistance to phonological processes such as assimilation and dissimilation, and the neutralisation of contrast outside of prominent positions. The unity of this array of privileged behaviours escapes notice in a derivational approach, where faithfulness effects arise either from a serendipitous absence of rules which apply to a prominent position, or from rules which apply to the complement of the prominent positions.

In Shona, the initial syllable restriction on contrastive mid vowels is derived via a high-ranking positional faithfulness constraint on height features, IDENT-σ_{i}(hi). The typologically marked mid vowels *e* and *o* enjoy a privileged existence in initial syllables due to the dominance of IDENT-σ_1(hi) over the height markedness constraint *MID. Such a ranking ensures that the underlying height of a vowel in the initial syllable is *always* faithfully reproduced on the surface, regardless of its markedness. Faithfulness to lexical material is paramount in the root-initial syllable, even when the lexical material in question is relatively more marked. However, mid vowels which are non-initial are not permitted in surface forms *unless* they share height features with a vowel in the privileged initial syllable. Faithfulness outside of the root-initial syllable is subordinated to markedness considerations. The facts of Shona implicate a ranking in which faithfulness to height in initial syllables takes precedence over height markedness constraints, which in turn dominate the more general height faithfulness constraints.

In this analysis, vowel harmony is initiated by the root-initial syllable, because faithfulness to underlying contrasts in this position is paramount – vowels in the root-initial syllable *never* undergo height harmony. Subsequent vowels must share the features of the first vowel in order to minimise violation of markedness constraints; a single multiply linked height specification incurs only one markedness violation, while multiple specifications incur multiple violations. Neither underspecification nor positional licensing of features (Itô 1986, 1989, Goldsmith 1989, 1990, Lombardi 1991, Steriade 1995) plays a role in the analysis.

In contrast, prior approaches to initial-syllable harmony languages like Shona make use of either underspecification or positional licensing restrictions. In an underspecification-based approach to Shona harmony (following vowel harmony proposals made by Bach 1968, Ringen 1975, Goldsmith 1985 and van der Hulst & Smith 1985, to name only a few), all vowels except that of the root-initial syllable are underlyingly unspecified for the feature [high]. An iterative, feature-filling harmony rule will later fill in the correct height values on non-initial vowels. While an empirically adequate derivational analysis is possible, it will be subject to the pointed critiques of underspecification recently adduced by McCarthy & Taub (1992) and Steriade (1995). Freely ordered blocks of assimilation rules, redundancy rules and cooccurrence filters will result in a grammar with an undesirably vast predictive capacity. Yet, as Steriade (1995) points out, attempts to impose universal limitations on the possible orderings of different rule types have met with only limited success.

In the OT analysis presented here, underspecification and its attendant complications play no role. The divergent phonological properties of initial and non-initial syllables arise from discrete faithfulness constraints and their interaction with a variety of markedness constraints, rather than from different degrees of specification in underlying forms. This positional faithfulness approach to Shona harmony also differs from the non-derivational INDIRECT LICENSING approach advocated in Steriade (1995), in which marked segments or features must be licensed via association to a prominent position. Positional faithfulness theory differs from licensing theory, in that positional faithfulness constraints both permit underlying marked segments to surface in prominent positions and prohibit marked elements from migrating to prominent positions in order to attain licensed status. Licensing theory alone cannot prevent the displacement of underlying structure in prominent positions.

The remainder of the paper is organised as follows. In §2, I present evidence of the privileged status of root-initial syllables, and introduce root-initial faithfulness constraints. Shona verb data and vowel harmony generalisations are presented in §3. In §4, the Optimality Theory framework and the constraints relevant to Shona are introduced. The analysis of Shona is presented in §5, and is contrasted with Optimality Theoretic feature alignment approaches to root-initial privilege in §6. In §7, I discuss the typological predictions of the position-sensitive identity framework. Finally, the implications of the current analysis are summarised in §8.

2 Positional faithfulness and root-initial syllables

The proposed inclusion of position-sensitive faithfulness constraints in the grammar raises an obvious question: what is the range of positions which can be referred to in such constraints, and what makes these positions available? I propose that the set of privileged licensing positions is a small, functionally defined class, consisting of those positions which are phonetically or psycholinguistically equipped to convey a wide range of marked features. The functional unity of this set is exploited in the grammar, in the form of positional faithfulness constraints which favour preservation of underlying lexical contrasts in just the positions which facilitate perception of those contrasts.

One source of motivation for positional faithfulness is found in the phonetic realm. Steriade (1993), in an overview of positional neutralisation phenomena, suggests that the set of linguistic positions which may serve as privileged licensers of contrast is defined in terms of perceptual facilitation. Marked or perceptually difficult contrasts are confined to positions in which they can be more easily discerned or produced, by virtue of phonetic factors such as increased duration, release of closure and segmental transition. Steriade discusses examples of privileged licensing in a variety of perceptually enhanced positions, including peripheral syllables, stressed syllables, long vowels, syllable onsets and syllable nuclei. Recent works by Padgett (1995, to appear) and Lombardi (1996) recruit this concept of perceptual facilitation, proposing positional faithfulness constraints in positions of consonantal release, in order to account for onset/coda asymmetries in licensing Laryngeal and Place features.

A second source of motivation for positional faithfulness may be found in the domain of lexical access and language processing. There is a considerable body of psycholinguistic research which indicates that word-initial material, either spoken or written, plays a key role in lexical access, word recognition and speech production. Some of this evidence is outlined in (4) below (see Hall 1988, 1992, Hawkins & Cutler 1988 for further examples and discussion of the relevant literature).

(4) *Word onset effects in processing*[3]

a. Word-initial portions make better cues for word recognition and lexical retrieval than either final or medial portions (Horowitz *et al.* 1968, 1969, Nooteboom 1981).

b. Word-initial material is most frequently recalled by subjects in a tip-of-the-tongue state (Brown & McNeill 1966).

c. Word onsets are the most effective cues in inducing recall of the target word in tip-of-the-tongue states (Freedman & Landauer 1966).

d. Mispronunciations are detected more frequently in word onsets than in later positions (Cole 1973, Cole & Jakimik 1978, 1980).

e. Mispronunciations in word onsets are less likely to be fluently replaced in a speech shadowing task than errors in later positions (Marslen-Wilson 1975, Marslen-Wilson & Welsh 1978).

From evidence of this type, Hawkins & Cutler (1988: 299) conclude that the temporal structure of lexical entries is 'of paramount importance' in the lexicon. They further 'suggest that the pervasiveness of onset salience, expressing itself not only in auditory comprehension but in reading as well, and in parallel effects in speech production, argues that the importance of the temporal structure of words in their mental representation extends beyond the auditory access code'. In this context, the predictions of Nooteboom (1981: 422) take on particular significance: 'lexical items will generally carry more information early in the word than late in the word. In phonological terms one would predict that (1) in the initial position there will be a greater variety of different phonemes and phoneme combinations than in word-final position, and (2) word initial phonemes will suffer less than word final phonemes from assimilation and coarticulation rules'.

Nooteboom's predictions appear to be borne out cross-linguistically. There are many examples of positional neutralisation which turn on the root-initial/non-initial syllable distinction. Some representative examples

language	*inventory includes*	*initial σ*	*non-initial σ*
Tuva (Turkic) (Krueger 1977)	plain & glottalised vowels	plain & glottalised vowels	no glottalised vowels
!Xóõ (Bushman) (Traill 1985)	click & non-click consonants	click & non-click consonants	no clicks
Tamil (Christdas 1988, Bosch & Wiltshire 1992)	high, mid & low vowels round & unround vowels	high, mid & low vowels round & unround vowels	no mid vowels no round vowels
Turkic family (Comrie 1981, Kaun 1995)	round & unround vowels	round & unround vowels	round vowels only after a round vowel in the initial syllable
Shona (Bantu) (Fortune 1955)	high, mid & low vowels	high, mid & low vowels	mid only after mid in the initial syllable
Dhangar-Kurux (Dravidian) (Gordon 1976)	oral & nasal vowels long & short vowels	oral & nasal vowels long & short vowels	no nasal vowels no long vowels
Shilluk (Nilotic) (Gilley 1992)	plain, palatalised & labialised consonants	plain, palatalised & labialised consonants	no palatalised or labialised consonants
Malayalam (Dravidian) (Wiltshire 1992)	labial, dorsal & a variety of coronal consonants	independent place of articulation in coda position	place of articulation in coda must be shared by following onset
Bashkir (Turkic) (Poppe 1964)	high & non-high vowels front and back vowels	high & non-high vowels front and back vowels	no high vowels front/back only in agreement with σ_1 vowel
Damin (Lardil secret language) (Hale 1973)[5]	Lardil segments, plus nasalised clicks, bilabial & velar ejectives, ingressive lateral fricative	Lardil segments, plus nasalised clicks, bilabial & velar ejectives, ingressive lateral fricative	no clicks, ejectives or lateral fricative

[Table I. Root-initial/non-initial inventory asymmetries] are provided in Table I.[4] Many more examples can be added to the compendium of languages in the table, but the selection is sufficient to demonstrate that root-initial position does indeed show a greater variety of sounds and possible combinations than do non-initial positions.

Nooteboom's second prediction, that word onsets should be more resistant to phonological change than word endings, is also supported by a variety of findings. Experimental evidence indicates that the application of fast-speech assimilation rules in two-word sequences preferentially affects the end of the first word, rather than the onset of the second (Cooper & Paccia-Cooper 1980; see also the discussion in Hall 1992 and Hume 1996). Naturally occurring examples provide additional evidence for initial-syllable resistance to change. Hume (1996) discusses the occurrence of metathesis in the Austronesian language Leti. In Leti, metathesis is a pervasive strategy employed in the satisfaction of a variety of phrase-level prosodic structure constraints. However, while metathesis applies freely to word-final sequences, it never applies in word-initial environments.[6] Zulu, a Bantu language of South Africa, is another example of initial resistance. In Zulu, labial consonants undergo a dissimilatory palatalisation process in the context of the passive suffix *-w* (Doke 1954, 1967, Beckman 1994). Thus the passive form of *guba* 'dig!' is *ayaguǰwa* 'it is being dug', not **ayagubwa*. When a labial-initial root is passivised, however, palatalisation fails to apply: *bala* 'write!', but *iyabalwa* 'it is being written', rather than **iyaǰalwa*.[7] These and similar cases demonstrate the resistance of segments in initial syllables to phonological alternation.

The psycholinguistic evidence reviewed above demonstrates clearly that initial syllables have a privileged processing status. Hawkins & Cutler (1988: 300) view this positional privilege as an accommodation of the language processing system to the 'temporal constraints of speech understanding'. They suggest that the structure of words in a language is further adapted to optimise the efficiency of the processing system, listing Nooteboom's (1981) proposals as examples of possible phonological adaptation. As we have seen, cross-linguistic evidence which instantiates Nooteboom's predictions is plentiful: phonological inventories are more rich in root-initial syllables than elsewhere, and initial syllables are preferentially resistant to phonological alternation. I propose that this asymmetry in the phonological properties of initial and non-initial syllables arises from a dispersion of Ident constraints, as shown in (5) below.[8]

(5) a. Ident-σ_1(hi)
A segment in the root-initial syllable in the output and its correspondent in the input must have identical values for the feature [high].

b. Ident(hi)
Correspondent segments in output and input have identical values for the feature [high].

With this constraint dispersion, faithfulness to underlying specifications in initial syllables may take precedence over markedness constraints, even when a context-free faithfulness constraint is overridden by markedness considerations. The high ranking of positional faithfulness constraints, relative to both the more general IDENT constraints and markedness constraints, yields the result that features and/or contrasts in *just those positions which are psycholinguistically or perceptually salient* are less susceptible to neutralisation than in other locations which are not protected. In Shona, the ranking of IDENT-σ_1(hi) above the vowel-height markedness constraints (see below) permits the full range of height contrasts to occur in initial syllables, and further renders these syllables impervious to height harmony. By contrast, the ranking of the context-free constraint IDENT(hi) below the markedness constraints renders non-initial syllables incapable of licensing marked vowels and further, susceptible to height harmony.

3 Shona: data and generalisations

Shona has a three-height vowel system comprised of five surface vowels. The vowels of Shona and the surface feature specifications assumed are shown in (6) below. (The generalisations which follow are based upon Fortune 1955, who describes the Zezuru dialect of Shona. However, vowel harmony applies in the other dialects of Shona as well.)

(6)	[back]	[round]	[high]	[low]
i	−	−	+	−
u	+	+	+	−
e	−	−	−	−
o	+	+	−	−
a	+	−	−	+

The distribution of the low vowel *a* is free in Shona verbs, but the occurrence of high and mid vowels is subject to certain limitations. In the initial syllable of a verb root, there are no restrictions on the occurrence of vowel features. However, in non-initial syllables, only [round], [back] and [low] may vary freely. The value of the feature [high] is determined by the height of a preceding vowel: mid vowels may appear non-initially only if preceded by a mid vowel. In order for a string of mid vowels to be licit, the leftmost vowel must appear in a root-initial syllable. (Thus, a sequence [CeCe], where C = any consonant, is not possible if preceded by a root-initial high or low vowel: *#[CiCeCe], *#[CaCeCe].)[9] High vowels may appear non-initially if the vowel of the preceding syllable is either high or low, but never if the preceding vowel is mid. This is summarised for $\#\sigma_1\sigma_2$ sequences in (7), where $\#\sigma_1$ indicates a root-initial syllable:

(7) σ_2 →

$\#\sigma_1$ ↓	i	u	e	o	a
i	√	√	▨	▨	√
u	√	√	▨	▨	√
e	▨	√	√	▨	√
o	▨	▨	√	√	√
a	√	√	▨	▨	√

Shaded cells in the table indicate non-occurring vowel sequences. Mid vowels may not follow either high or low vowels, while high vowels may not follow mid. This is true both within verb roots and between roots and suffixes in derived stems.

The sole exception to this generalisation is found in the sequence #[CeCu]; non-initial round vowels harmonise in height with a preceding vowel only if the vowels agree in rounding. This is manifested in the absence of #[CeCo] sequences and the presence of #[CeCu], as indicated in (7). I will ignore this gap in the remaining discussion of data and generalisations, but return to it in §5 below.

Data instantiating these distributional generalisations are given in (8)–(12) below. In (8), representative examples of polysyllabic verb roots are provided.[10] There are no polysyllabic roots in Shona which fail to exhibit vowel harmony; the cooccurrence patterns in (7) are robustly maintained here, as in the derived forms shown (9)–(12). (For reference, I have provided an exhaustive list of verbal extensions, both productive and unproductive, in (13).)

(8) *Polysyllabic roots exhibit vowel harmony*[11]

tonhor-	'be cold' Fi
nonok-	'dally, delay' F7
nonot-	'scold, abuse' H
korokod-	'itch (nostril)' H
gobor-	'uproot' F7
bover-	'collapse inwards' H
kobodek-	'become empty' H
chenjer-	'be wise' M
chember-	'grow old' M
verer-	'move stealthily' M
vereng-	'read, count' M
pember-	'dance for joy' H
nyemwerer-	'smile' F7
pofomadz-	'blind (TRANS)' F5
pofomar-	'be blind' H
chonjomar-	'sit with buttocks and soles of feet on ground' H
zendam-	'lean with support at side or back' H
chenam-	'bare teeth angrily' H

fungat-	‘embrace’ D
pfugam-	‘kneel’ F7
ruram-	‘be straight’ F7
bvinar-	‘fade’ H
findam-	‘tangle (INTR)’ H
minaik-	‘wriggle’ H

buruk-	‘dismount’ F7
dukup-	‘to be small’ H
kumbir-	‘ask for’ M
turikir-	‘translate’ Fi
simuk-	‘stand up’ F7
simudz-	‘lift’ Fi
kwipur-	‘uproot’ H
svetuk-	‘jump’ F5
serenuk-	‘water (gums of mouth)’ H

charuk-	‘jump over/across’ H
ganhur-	‘limit, demarcate’ H
katuk-	‘flicker (flame)’ H
tandanis-	‘chase’ Fi
kwazis-	‘greet’ F7

(9) *Root + applicative* (Fortune 1955)

a.	pera	‘end’	per-e̲ra	‘end in’
	tsveta	‘stick’	tsvet-e̲ra	‘stick to’
	sona	‘sew’	son-e̲ra	‘sew for’
	pona	‘give birth’	pon-e̲ra	‘give birth at’
b.	ipa	‘be evil’	ip-i̲ra	‘be evil for’
	ɓata	‘hold’	ɓat-i̲ra	‘hold for’
	vava	‘itch’	vav-i̲ra	‘itch at’
	svetuka	‘jump’	svetuk-i̲ra	‘jump in’
	pofomadza	‘blind’	pofomadz-i̲ra	‘blind for’

(10) *Root + neuter* (Fortune 1955)

a.	gona	‘be able’	gon-e̲ka	‘be feasible’
	vereŋga	‘count’	vereŋg-e̲ka	‘be numerable’
	cheŋgeta	‘keep’	cheŋget-e̲ka	‘get kept’
b.	kwira	‘climb’	kwir-i̲ka	‘easy to climb’
	bvisa	‘remove’	bvis-i̲ka	‘be easily removed’
	tarisa	‘look at’	taris-i̲ka	‘easy to look at’

(11) *Root + perfective* (Fortune 1955)

a.	pota	‘go round’	pot-e̲re̲ra	‘go right round’
	cheka	‘cut’	chek-e̲re̲ra	‘cut up small’
	seka	‘laugh’	sek-e̲re̲ra	‘laugh on and on’
b.	pinda	‘pass’	pind-i̲ri̲ra	‘to pass right through’
	ɓuɗa	‘come out’	ɓuɗ-i̲ri̲ra	‘to come out well’

(12) *Root + causative* (Fortune 1955)

a.	tonda	‘face’	tond-e̲sa	‘make to face’
	shoŋga	‘adorn self’	shoŋg-e̲sa	‘make adorn’
	oma	‘be dry’	om-e̲sa	‘cause to get dry’
b.	bvuma	‘agree’	bvum-i̲sa	‘make agree’
	shamba	‘wash’	shamb-i̲sa	‘make wash’
	pamha	‘do again’	pamh-i̲sa	‘make do again’
	cheyama	‘be twisted’	cheyam-i̲sa	‘make be twisted’

(13) *Shona verbal extensions* (Doke 1967: 66–67; Fortune 1955)

-w, -iw/-ew	PASSIVE
-ir/-er	APPLICATIVE
-ik/-ek	NEUTER
-is/-es, -y	CAUSATIVE
-idz/-edz	CAUSATIVE
-is/-es, -isis/-eses	INTENSIVE
-irir/-erer	PERFECTIVE
-an	RECIPROCAL
-uk/-ok, -uruk/-orok	REVERSIVE[12]
-ur/-or, -urur/-oror	REVERSIVE
-aur	EXTENSIVE
-at	CONTACTIVE (not synchronically productive)
-am, -ar	STATIVE (not synchronically productive)

The data in (8)–(12) demonstrate that high and mid vowels in Shona are not freely distributed in the verbal system. Rather, the height of the root-initial vowel determines the height of any subsequent non-low vowels. If the initial vowel is [−high, −low], following vowels must share that [−high] specification; if the initial vowel is [+high] or [+low], no mid vowels may appear subsequently. Forms such as *cheyamisa* ‘make be twisted’ and *pofomadzira* ‘blind for’ demonstrate that the low vowel *a* is opaque to harmony, constituting a barrier to the extension of a multiply linked [−high]. Following a low vowel, no further mid vowels may appear: instead, the typologically less marked high vowels are invariably found. Before turning to the analysis of height distribution in Shona, the theoretical framework and constraints assumed are set out in §4.

4 The Optimality Theory framework

4.1 Background: optimality and correspondence

Optimality Theory is a framework in which the emphasis is not on a sequence of ordered rules by which an input is transformed into a surface form, but rather on the interaction of violable universal constraints which determine the well-formedness of output forms. The task of the analyst is therefore not to determine what rules apply and in what order in a given language, but instead to determine the ranking of constraints which will generate all and only the surface phonological patterns of a language.

The OT grammar consists of the following components (Prince & Smolensky 1993): *Con*, a set of violable universal constraints, ranked on a language-particular basis, against which the well-formedness of output candidates is evaluated; a function *Gen*, which associates an input form with a potentially infinite set of output candidates; and a function *Eval*, which assesses output candidates and orders them according to how well they satisfy the constraint system of the language in question. The actually occurring output form is that candidate which best satisfies the constraint system.

Optimality Theory makes the strong claim that cross-linguistic variation derives entirely from permuted ranking of universal constraints. One corollary of this claim is the principle of RICHNESS OF THE BASE (Prince & Smolensky 1993: 191): there is a single, universal set of inputs to the grammars of all languages. Applied to this universal input set, each constraint ranking will converge on a set of grammatical outputs; different constraint rankings result in different surface inventories, filtering out all ill-formed patterns. On this view, 'the lexicon of a language is a sample from the inventory of possible inputs; all properties of the lexicon arise indirectly from the grammar, which delimits the inventory from which the lexicon is drawn' (Tesar & Smolensky 1996: 43).

Richness of the Base follows from the strict output orientation of OT, but it has important ramifications for the elimination of redundancy in the phonological component of grammar. It has long been noted that phonological generalisations hold not only of morphologically complex forms, but also of underived lexical items (see, for example, Halle 1959, 1964, Chomsky & Halle 1968, Kiparsky 1973, 1982, Lightner 1973, Shibatani 1973, Skousen 1973, Kaye 1974, Kenstowicz & Kisseberth 1977). However, the characterisation of restrictions on morpheme structure in a rule-based theory of phonology raises a variety of problems, as Kenstowicz & Kisseberth (1977: ch. 3) discuss. Among these is the Duplication Problem: if morpheme structure constraints are formally distinct from phonological rules, the grammar necessarily requires two separate mechanisms to account for a single set of phonological generalisations (see Kenstowicz & Kisseberth 1977: 136, and, for more extensive discussion, Ringen 1975). OT avoids the Duplication Problem, because, as discussed above, apparent restrictions on the structure of the underlying representations arise in the same way as restrictions on the structure of derived surface forms: from the interaction of output well-formedness constraints.[13]

Given an input form, the function *Gen* provides a set of candidate outputs which are consistent with that input, drawing on representational primitives of linguistic form and the basic modes of combining those primitives (McCarthy 1995). Departing from earlier work in OT (McCarthy & Prince 1993a, b, Prince & Smolensky 1993), CONTAINMENT, a property of *Gen* which requires that all input material be literally contained in the output candidates, is supplanted here by the theory of

CORRESPONDENCE developed in McCarthy & Prince (1995). McCarthy & Prince note that a wide range of parallels exist between requirements on base–reduplicant identity in reduplicative morphology on the one hand, and requirements of input–output faithfulness in phonology on the other. Generalising over the two domains, McCarthy & Prince propose that candidate sets come from *Gen* with a correspondence function expressing the dependency of the output on the input (or of the reduplicant on the base).

(14) *Correspondence* (McCarthy & Prince 1995)
Given two related strings S_1 and S_2 (underlying and surface), correspondence is a relation $\Re$ from the elements of S_1 to those of S_2. An element $\alpha \in S_1$ and any element $\beta \in S_2$ are referred to as CORRESPONDENTS of one another when $\alpha \Re \beta$.

Along with the notion of correspondence, McCarthy & Prince propose that Universal Grammar includes various types of constraints on correspondent elements, supplanting the PARSE and FILL faithfulness constraints of Prince & Smolensky (1993). The function *Eval* considers each candidate pair S_1,S_2 and its correspondence function, assessing the relation between S_1 and S_2 with respect to the constraints on correspondence. Some examples of correspondence constraints are given in (15).[14]

(15) a. MAX: Every segment in S_1 has a correspondent in S_2.
(Phonological deletion is not permitted.)
b. IDENT(F): Correspondent segments in S_1 and S_2 have identical values for some feature [F].[15]
(Features may not be changed.)
c. DEP: Every segment in S_2 has a correspondent in S_1.
(Phonological insertion is not permitted.)

In this paper, I focus on the elaboration of the IDENT constraints, and the interaction of these constraints with featural markedness constraints.

4.2 The constraints

The key generalisation concerning the distribution of non-low vowels in Shona is the inalterability of root-initial input height specifications. Subsequent vowels which are non-low either agree in height with a preceding vowel or are [+high]. In terms of correspondence, this can be seen as the result of a higher premium being placed on the maintenance of underlying contrasts in initial syllables than elsewhere in the word. This contrast in the restrictions on initial and non-initial feature specifications can be captured via the dispersion of the featural identity constraint IDENT(hi) into two discrete constraints, one specific to root-initial syllables (16a) and the other (16b) assessing faithfulness in any context.

(16) a. IDENT-σ_1(hi)
A segment in the root-initial syllable in the output and its correspondent in the input must have identical values for the feature [high].
b. IDENT(hi)
Correspondent segments in output and input have identical values for the feature [high].

In Shona, the asymmetry between initial and non-initial syllables in assessing faithfulness to underlying height contrasts argues for the ranking in (17):[16]

(17) IDENT-σ_1(hi) $\gg$ IDENT(hi)

IDENT constraints are evaluated with respect to correspondent segments, rather than correspondent features; featural relations between input and output are transmitted via the segmental unit.

In addition to the constraints shown in (16), a further IDENT constraint is required to account for the inertia of the low vowel *a*. Recall that low vowels are impervious to height harmony; input low vowels in non-initial syllables remain low when preceded by high or mid vowels. Further, low vowels in the root fail to trigger harmonic behaviour in suffixes; suffix vowels which alternate display only a two-way alternation between high and mid. The complete inalterability of input low vowels indicates an undominated IDENT(lo) constraint:

(18) IDENT(lo)
Correspondent segments in input and output are identical with respect to the feature [low].

In addition to the faithfulness constraints outlined above, the grammar also contains a variety of featural markedness constraints. I follow the proposal of Prince & Smolensky (1993) and Smolensky (1993) that universal harmony scales, each of which encodes the relative markedness of all features or values along a particular dimension such as place of articulation or height, are reflected in the grammar by means of corresponding constraint subhierarchies. Various surveys of vowel inventory structure (Crothers 1978, Disner 1984) indicate that the presence of mid vowels in an inventory implies the presence of high and low vowels, while the reverse is not true. The universal harmony scale which reflects this implication is given in (19a), with the corresponding constraint dominance hierarchy in (19b):

(19) a. *Height markedness: harmony scale*
High, Low > Mid
b. *Height markedness: dominance hierarchy*[17]
*MID $\gg$ *HIGH, *LOW

The constraints in (19b) are instantiated in (20):

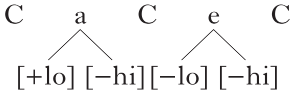
(20) a. *Mid: *[−high, −low]
b. *High: *[+high, −low]
c. *Low: *[−high, +low]

Through the interaction of the featural markedness constraints above with the Ident(hi) constraints, the distribution of vowel height in the surface inventory of a language is determined. Following Prince & Smolensky's (1993) proposals for the characterisation of segmental inventory structure, the ranking of *Mid ≫ Ident(hi) will generate a language with no mid vowels. The opposite ranking, Ident(hi) ≫ *Mid, will result in a language with surface mid vowels (as well as high and low, given the universal hierarchy in (19b)).[18] All else being equal, the ranking in (19b) will yield the result that high vowels are preferred to mid. This holds both in Shona and in the languages of the world more generally.

5 The analysis

I turn now to the details of the Shona analysis, the core properties of which derive from the interaction of faithfulness and markedness constraints. Recall that the height of non-low vowels is predictable in Shona verbs,[19] outside of the root-initial syllable. Verbs containing a mid vowel in the initial syllable consist entirely of mid vowels, while the vowels in verbs whose initial syllable contains a high vowel are uniformly high. There are no verbs of the shape [CiCeC] or [CeCiC] in Shona. Further, if the initial syllable contains a low vowel, subsequent vowels may not be mid: *[CaCeC].[20]

The latter fact, the absence of low–mid sequences in the inventory of Shona verb root shapes, demonstrates that *Mid ≫ Ident(hi). Consider a hypothetical input of the form /CaCeC/, shown in (21):[21]

(21)


An input mid vowel in this position is *never* faithfully reproduced in the optimal output form, indicating that *Mid dominates the general Ident(hi) constraint, and that *Mid ≫ *High. This is demonstrated in (22):[22]

(22) *Mid ≫ Ident(hi), *High

/CaCeC/	*Mid	Ident(hi)	*High
a. C a C e C [+lo] [−hi] [−lo] [−hi]	*!		
☞ b. C a C i C [+lo] [−hi] [−lo] [+hi]		*	*

The optimal candidate (22b) violates Ident(hi) and *High, while the fully faithful (22a) violates only *Mid. *Mid must dominate each of the other constraints in order to account for the absence of forms such as (22a); any ranking in which either Ident(hi) or *High dominates *Mid incorrectly predicts that (22a) is optimal.

The same output form, [CaCiC], is generated by the constraint system when given a /CaCiC/ input. This is shown in (23), where the candidate including a high vowel is again victorious due to the ranking *Mid ≫ Ident(hi):

(23) /CaCiC/ *input; e.g.* kwazis- *'greet'*

/CaCiC/	*Mid	Ident(hi)	*High
a. C a C e C [+lo] [−hi][−lo] [−hi]	*!	*	
☞ b. C a C i C [+lo] [−hi][−lo] [+hi]			*

As discussed in §4.1 above, OT assumes that the markedness constraints contained in UG are evaluated with respect to output forms. Language-particular variation derives from permutations in the ranking of such constraints, and not from restrictions on input forms. This is the principle of Richness of the Base: the set of input forms is universal, but due to permutation of constraint ranking, different languages arrive at different inventories of grammatical output forms. For example, the ranking *Mid ≫ *High, Ident(hi) in Shona guarantees that non-low vowels which follow an initial *a* must always surface as [+high]. Were Ident(hi) to dominate *Mid, the result would be a different language, one in which non-initial vowels are freely high or mid. From the same set of input forms, /CaCiC/ and /CaCeC/, different output results will be obtained.

The discussion thus far has focused on an account of possible *vs.* impossible surface forms, without reference to instantiated Shona verbs. The output orientation of OT brings with it Richness of the Base, meaning that all manner of different possible inputs must converge on the occurring surface inventory of a language, via the constraint ranking which characterises the grammar of that language. However, there is a distinction to be made between possible *input forms* and plausible *underlying representations* for actual lexical items. In general, many different inputs may converge on a particular output form, but only that input which diverges minimally from the output will be selected by the language learner as the lexical representation. (The degree of abstractness permissible in underlying representation has been extensively debated in the generative phonological literature. Kiparsky's 1968 Alternation Condition represents one well-known approach to abstractness; Kenstowicz & Kisseberth 1977: ch. 1 reviews the issue in some detail.) In Optimality Theory, the principle of Lexicon Optimisation (Prince & Smolensky 1993, Itô *et al.* 1995) is proposed as a means of determining the correct underlying representation:

(24) *Lexicon Optimisation* (formulation from Itô *et al.* 1995)

> Of several potential inputs whose outputs all converge on the same phonetic form, choose as the real input the one whose output is the most harmonic.

Given a choice of inputs which yield the same surface result, the language learner will select as the underlying representation that input which most closely resembles the output form.

Let's consider a concrete case, the Shona verb root *kwazis*- 'greet'. Following the examples of (22) and (23) above, two possible inputs for this form are /kwazes-/, with an underlying mid vowel, and /kwazis-/, with an underlying high vowel. As tableaux (22) and (23) show, both inputs will converge on the same phonetic output. Lexicon Optimisation dictates that /kwazis-/ will be selected as the actual underlying form. The output in (23b) incurs fewer violations with respect to /kwazis-/ than does the output (22b) with respect to the input /kwazes-/. This is demonstrated in the *tableau des tableaux* in (25):

(25) *Evaluating outputs of possible input forms*

input	*output*	*Mid	Ident(hi)	*High
a. kw a z e s [+lo][−hi][−lo][−hi]	☞ kw a z i s [+lo][−hi][−lo][+hi]		*!	*
☞ b. kw a z i s [+lo][−hi][−lo][+hi]	☞ kw a z i s [+lo][−hi][−lo][+hi]			*

By Lexicon Optimisation, the input vocalism in (25b) will be selected as the underlying form of the root in [kwazisa], because the mapping between input and output in (25b) incurs fewer violations than that in (25a).[23]

The constraint system employed in (22) and (23), while providing the correct results for simple low–non-low roots, is not sufficiently rich to account for all of the Shona data. Without additional constraints, simple [CeC] roots are predicted to be unavailable in the language, since the markedness constraint *Mid dominates Ident(hi). This ranking will result in the obliteration of all mid vowels in surface forms; an input [−high] specification will always be rendered [+high] in outputs in order to satisfy the high-ranking *Mid, even at the expense of Ident(hi). Thus, in order to correctly allow verb roots such as *per*- 'end' and *son*- 'sew' to surface, the contraint system must be augmented. Specifically, *Mid must be dominated by a constraint which permits mid vowels to appear in the privileged root-initial position.

The constraint in question is the positional identity constraint Ident-σ_1(hi). Mid vowels are permitted to surface just in case they are contained in the root-initial syllable; preservation of underlying contrasts in this position takes precedence over the markedness considerations which otherwise serve to rule out mid vowels. That is, Ident-σ_1(hi) $\gg$ *Mid $\gg$

Ident(hi). This innovation provides the desired result: otherwise inadmissible [−high] specifications are permitted to surface if and only if they are linked to a vowel in the root-initial syllable. Elsewhere, the contrast between [+high] and [−high] is neutralised.

To demonstrate the workings of this simple constraint system, consider first a basic /CeC/ root. With the addition of the positional identity constraint, the tableau in (26) is generated:

(26) *Correct generation of initial mid vowel from /*CeC*/ input;*
e.g. per- *'end'*

/per-/	Ident-σ_1(hi)	*Mid	Ident(hi)	*High
☞ a. p e r [−lo] [−hi]		*		
b. p i r [−lo] [+hi]	*!		*	*

If *Mid were to dominate Ident-σ_1(hi), mid vowels would be ruled out in all positions, including the root-initial syllable. That is, a three-vowel (*a*, *i*, *u*) system would result, since input mid vowels would never be permitted to surface.

The correctness of the constraint ranking in (26) is further supported when more elaborate candidates are taken into account. For example, consider the hypothetical input in (27):

(27) C e C i C
[−lo] [−hi] [−lo] [+hi]

This candidate allows the correct ranking of *High and Ident(hi) to be established, as shown in (28):

(28) Ident-σ_1(hi) ≫ *Mid ≫ *High ≫ Ident(hi)

/CeCiC/	Ident-σ_1(hi)	*Mid	*High	Ident(hi)
a. C e C i C [−lo] [−hi] [−lo] [+hi]		*	*!	
☞ b. C e C e C Aperture [−lo] [−hi]		*		*
c. C e C e C [−lo] [−hi] [−lo] [−hi]		**!		*
d. C i C i C Aperture [−lo] [+hi]	*!		*	*

IDENT(hi) must be dominated by both of the markedness constraints in order to explain the neutralisation of the non-initial [+high] specification. The ranking *HIGH $\gg$ IDENT(hi) results in the 'spreading' candidate, (28b), being optimal, as (28d), in which the input mid vowel is supplanted by a high vowel in the output, violates the high-ranking positional IDENTITY constraint. Were IDENT(hi) to dominate *HIGH, the faithful candidate (28a) would be optimal; the language would have mid vowels only in root-initial syllables, but would lack vowel harmony. In (28b), the *MID violation is compelled by the dominant IDENT-σ_1(hi); thus, the non-initial mid vowel is licensed in spite of its marked status. In the case of (28b), it is important to note that only one violation of *MID occurs, as only one [−high, −low] feature complex, dominated by an Aperture node, is shared by both vowels. This differs from the situation in (28c), where two *MID violations are assessed. The evaluation of constraint satisfaction for constraints of the form *F, *[F,G] proceeds in a bottom-up, feature-based manner, rather than being top-down or segment-based. Violations are not determined according to how many mid vowels appear in a candidate, but by the number of discrete autosegments or combinations of autosegments present in the candidate. This is formalised in the principle of Feature-Driven Markedness in (29).[24]

(29) *Feature-Driven Markedness*

Let S denote a set of features $\{\alpha, \beta, \gamma, \ldots\}$ and *S a markedness constraint prohibiting the cooccurrence of the members of S.

*S receives one violation-mark for each node N, where
N dominates all features in S *and*
there is no node M such that N dominates M and M also dominates all features in S

In the case of singleton feature markedness constraints such as *LABIAL, *DORSAL and *CORONAL, the Place markedness constraints of Prince & Smolensky (1993), S = {Labial}, {Dorsal} or {Coronal} and the node N = Labial, Dorsal or Coronal (assuming that domination is a reflexive relation (Wall 1972, Bach 1974, Cushing 1978, Johnson 1978, Pullum & Zwicky 1978)). Thus, one violation mark for *LABIAL is assessed for each occurrence of the feature Labial in an output form; multiple Labial specifications incur multiple violations of markedness constraints, while multiple linkings of a single feature do not.[25] By contrast, in the case of markedness constraints which evaluate feature combinations, such as *[−high, +low] (*LOW), *[−high, −low] (*MID), etc., (29) calls for violations to be assessed for each discrete node which immediately dominates the relevant feature set. For the height features, this is the Aperture node (Clements & Hume 1995, and references therein). This distinguishes the harmonising and multiply linked (28b) from the sequence of singly linked identical vowels in (28c). Linking at the Aperture node is required to minimise markedness violations; sequences of vowels which are phonetically identical but separately specified are more marked, and hence, non-optimal.

Tableau (28) illustrates height neutralisation and vowel harmony when the initial syllable of the input contains a mid vowel. When the height of the vowels is reversed (i.e. the input is /CiCeC/), parallel results obtain: non-initial specifications are neutralised, with multiple linking of an initial [+high]. This is demonstrated in (30):

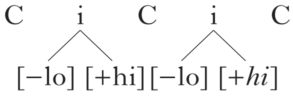
(30) *Height harmony with a* /CiCeC/ *input*

/CiCeC/	Ident-σ_1(hi)	*Mid	*High	Ident(hi)
a. C i C e C [−lo] [+hi] [−lo] [−hi]		*!	*	
☞ b. C i C i C Aperture [−lo] [+hi]			*	*
c. C e C e C Aperture [−lo] [−hi]	*!	*		*

Candidate (30c), in which the non-initial [−high] specification has supplanted the input specification of the initial syllable, is ruled out due to a violation of the high-ranking Ident-σ_1(hi). The faithful parse, (30a), incurs a violation of *Mid, which (30b) does not. As neither candidate violates Ident-σ_1(hi), the *Mid violation is fatal to (30a).

Before assuming that multiple linking of the initial specification to all vowels is the correct representation for the uniform height of the output, however, an alternative should be considered: insertion of a non-input [+high]. That is, the output candidate in (31) must also be evaluated (the non-input [+high] is italicised):

(31)



While this candidate and the multiply linked candidate in (30b) are phonetically equivalent, they differ with respect to markedness. The second vowel cannot share the Aperture node of the first while also bearing an inserted, 'default' [+high] specification; two distinct Aperture nodes are required.[26] Two violations of *High are therefore incurred by such a candidate. Discrete feature specifications, even of a relatively unmarked feature, are more costly than a multiple linking of a single feature or node. This is demonstrated in (32):

(32) *Multiple linking is more harmonic than multiple specifications;*
CiCeC *input*

/CiCeC/	Ident-σ_1(hi)	*Mid	*High	Ident(hi)
a. C i C e C [−lo] [+hi][−lo] [−hi]		*!	*	
☞ b. C i C i C Aperture [−lo][+hi]			*	*
c. C e C e C Aperture [−lo][−hi]	*!	*		*
d. C i C i C [−lo] [+hi][−lo] [+*hi*]			**!	*

Parallel to the situation in (28) above, the multiply linked Aperture node of (32b) incurs only one violation of *High. In contrast, the separate feature specifications in (32d) incur two violations.[27]

We have seen that the absence of asymmetric height in verb roots containing non-low vowels is compelled by the constraint ranking shown in (33):

(33) Ident-σ_1(hi) $\gg$ *Mid $\gg$ *High $\gg$ Ident(hi)

The ranking of *Mid and *High over Ident(hi) forces non-initial [high] specifications to be obliterated; markedness considerations take precedence over an exact input–output correspondence. In order to satisfy the requirement that output vowels have height, the [high] specification of the initial syllable is multiply linked to the subsequent vowels. Such an arrangement both satisfies the high-ranking Ident-σ_1(hi) and avoids multiple violations of *Mid or *High. (The root-initial specification of [high] necessarily incurs a violation of either *Mid or *High, of course, under compulsion of Ident-σ_1(hi).)

To understand the relationship of low vowels to the restrictions on vowel height in non-low vowels, we return to the hypothetical /CaCeC/ input of (22) above. In such situations, when no root-initial [high] specification is available, multiple linking of [high] or of an Aperture node is not a possible means of licensing a non-initial mid vowel. Rather, a [+high] vowel *i* surfaces in non-initial syllables. This demonstrates that Ident(lo) dominates *High (thus, [CaCiC] would be the result of a /CaCeC/ input, rather than [CaCaC]). This, in combination with the independently motivated ranking *Mid $\gg$ *High, accounts for the absence of [CaCeC] verbs, as shown in (34):

(34)

/CaCeC/	Ident(lo)	Ident-σ_1(hi)	*Mid	*High	Ident(hi)
a. C a C e C [+lo] [−hi] [−lo] [−hi]			*!		
b. C a C a C Aperture [+lo] [−hi]	*!				*
c. C a C e C Aperture Aperture [+lo] [−hi] [−lo]			*!		
☞ d. C a C i C [+lo] [−hi] [−lo] [+hi]				*	*

Multiple linking of a single [−high] specification, as in (34c), does not result in a minimisation of *Mid violations. In both (34a) and (34c), a *Mid violation is incurred. Candidate (34d) violates only the lower-ranking *High and is therefore optimal.

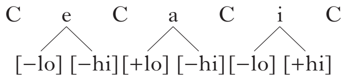
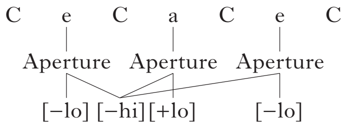
The failure of height harmony across the low vowel *a* in forms such as *pofomadzira* 'blind for' and *bodanira* 'be overcooked for' is explained in much the same way as the absence of [CaCeC] roots in general. Any mid vowel which follows a low vowel necessarily has its own Aperture node, as we saw in (28), even if a single [−high] specification may be multiply linked to both vowels. Non-low vowels which follow a low vowel *a* must necessarily surface as the less marked high vowel, even when the initial syllable contains a licit mid vowel. This is illustrated in (35), with an input /bodanir-/:

(35) *Harmony fails across an intervening low vowel*

/bodanir-/	Ident (lo)	Ident-σ_1 (hi)	*Mid	*High	Ident (hi)
☞ a. b o d a n i r [−lo] [−hi] [+lo] [−hi] [−lo] [+hi]			*	*	
b. b o d a n e r Aperture Aperture Aperture [−lo] [−hi] [+lo] [−lo]			**!		*
c. b o d e n e r Aperture [−lo] [−hi]	*!		*		*

The fully harmonising candidate (35c) fatally violates Ident(lo) in its quest to achieve minimal markedness violations. In order to arrive at the single shared Aperture node which is necessary to compete with candidate (35a) on *Mid, the [low] specification of the input low vowel is necessarily altered, and this alteration is fatal. Candidate (35b), in which only the [−high] specification of the initial vowel is multiply linked, incurs an additional violation of *Mid which is not assessed for candidate (35a). That additional violation is fatal, and the candidate in which the rightmost vowel is [+high] is favoured. This is true even if the input is assumed to contain two mid vowels flanking a low vowel, as in (36), where the input assumed is the hypothetical /CeCaCeC/. High-ranking *Mid and the feature-driven character of markedness constraints conspire to prohibit the more marked mid vowels after *a*.

(36) *Mid vowels may not be preserved after* /a/

/CeCaCeC/	Ident (lo)	Ident-σ_1 (hi)	*Mid	*High	Ident (hi)
☞ a. 			*	*	*
b. 			**!		

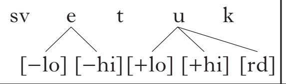
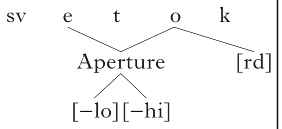
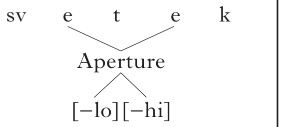
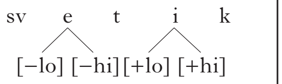
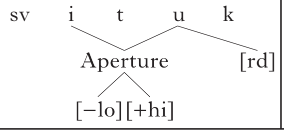
Although the faithful candidate (36b) incurs no violations of Ident(hi), it does incur two violations of the higher-ranking *Mid. As before, this profusion of markedness violations is fatal; the unmarked character of the high vowel *i* is the key to its appearance following *a*.

The final matter to be addressed here is the failure of height harmony in *e … u* sequences, and the absence of otherwise expected *e … o* sequences. As noted in §3, non-low vowels may disagree in height just in case an initial front mid vowel *e* is followed by a round vowel; when the initial mid vowel is round, subsequent round vowels are also mid. Thus, we find *svetukira* 'jump in', rather than the expected **svetokera*, but *pofomadza* 'blind', *gobora* 'uproot', etc., are well-formed (**pofumadza*, **gobura*). Kaun (1995), in an examination of rounding harmony systems, surveys articulatory, perceptual and typological studies of vowel rounding. She reports that non-high round vowels are produced with less lip rounding and protrusion than high round vowels (Linker 1982). This articulatory disparity is mirrored in the perceptual domain: non-high round vowels are perceived as being relatively less rounded than their high counterparts (Terbeek 1977). Finally, rounding on low vowels is extremely rare in the languages of the world (Maddieson 1984). Drawing on this evidence, Kaun argues that rounding in non-high vowels is disfavoured because the lower jaw position necessary to produce non-high vowels is antagonistic to lip rounding and lip protrusion gestures. She proposes the articulatorily motivated markedness constraint *RoLo:[28]

(37) *RoLo (Kaun 1995: 144)
Vowels should not be simultaneously specified [+round] and [−high].

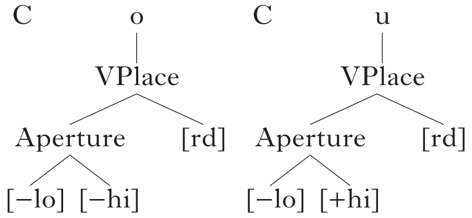
Any output combination of [−high, round] will incur a violation of this constraint, which must dominate *Mid in order to prevent the creation of non-initial *o*. The presence of *e…u* sequences in the Shona surface inventory indicates that Ident(round) is also high-ranking; underlying *e…u* does not surface as *e…e* in order to better satisfy *Mid. This is illustrated in (38):

(38) *Height harmony is blocked by* *RoLo

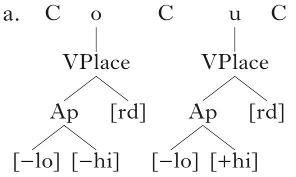
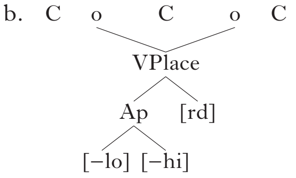
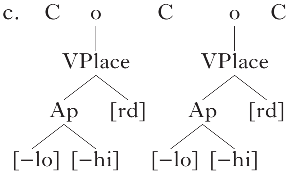
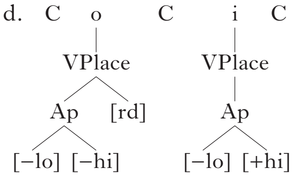
/svetuk-/	Ident-σ_1 (hi)	Ident (rd)	*RoLo	*Mid	*High	Ident (hi)
☞ a.  sv e t u k [−lo] [−hi] [+lo] [+hi] [rd]				*	*	
b.  sv e t o k Aperture [rd] [−lo] [−hi]			*!	*		*
c.  sv e t e k Aperture [−lo] [−hi]		*!		*		*
d.  sv e t i k [−lo] [−hi] [+lo] [+hi]		*!		*	*	
e.  sv i t u k Aperture [rd] [−lo] [+hi]	*!				*	*

The optimal candidate, (38a), better satisfies the constraint hierarchy than any competitors. Preservation of rounding and maintenance of initial syllable vowel height are paramount; candidates (38c–e) fail in this regard. (38b) fails on high-ranking *RoLo, leaving only (38a).

High-ranking *RoLo prevents the creation of non-initial *o* following a mid *e* in forms such as *svetukira*. This is the desired result, but the constraint hierarchy must not rule out all instances of non-initial *o*, as there are forms such as *pofomadza* in the language. The non-initial *o* in this and parallel forms is preferred by the constraint system, as demonstrated in (40). Here I assume a height-disharmonic input whose vowels have separate [round] specifications, as in (39). (Input *o . . . o* sequences will also be correctly admitted by the constraint in (40); the input in (39) is more interesting, as it shows that height harmony will result, even in the event that the input heights differ.)

(39)


(40) *Height harmony is required when vowels agree in rounding*

/CoCuC/	Ident-σ_1 (hi)	Ident (rd)	*RoLo	*Mid	*High	Ident (hi)
a. 			*	*	*!	
☞ b. 			*	*		*
c. 			**!	**		*
d. 		*!	*	*	*	

In this case, high-ranking *RoLo militates in favour of the structure in (40b), in which a single [−high] and [round] specification, dominated by one VPlace node (Odden 1991; see also the Vocalic node of Clements & Hume 1995), is shared by both vowels.[29] The principle of Feature-Driven Markedness ((29) above) requires that (40b) be assigned only one violation-mark for *RoLo because there is a single node, VPlace, which dominates the targeted feature set {[round], [−high]}. By the same principle, two violations of *RoLo are assigned to (40c), because there are two VPlace nodes in the output.[30] Unrounding the non-initial vowel (40d) will avoid an extra violation of *RoLo, but at the expense of undominated Ident(round). Finally, the fully faithful candidate (40a) fails by virtue of its *High violation; height-harmonic and optimal (40b) avoids this violation.

As the preceding discussion has demonstrated, the distribution of non-low vowels in Shona verbs is accounted for tidily by the interaction of markedness and faithfulness constraints. The privileged licensing status of the root-initial syllable results from the high-ranking Ident-σ_1(hi), which forces input–output correspondence in the root-initial position, even for the more marked mid vowels. This is due to the ranking of Ident-σ_1(hi) above both of the featural markedness constraints *Mid and *High.

The persistence of initial values of [high] through vowel harmony follows from the feature-based character of the markedness constraints *Mid and *High. Following the principle of Feature-Driven Markedness (29), multiple features or nodes incur more violations than do singleton features or nodes. This means that a single multiply linked feature is more harmonic than two or more individual feature specifications. The same is true of class nodes which dominate marked feature combinations. Thus, feature sharing occurs whenever possible, resulting in uniform height in the output; underlying *e…i* surfaces as *e…e* (28), while underlying *i…e* surfaces as *i…i* (30).

Finally, the fact that only high vowels may surface after the low vowel *a* is an emergence of the unmarked effect (McCarthy & Prince 1994a) which arises through the ranking of *Mid and *High. *Mid dominates *High; thus, all else being equal, a high vowel is more harmonic than a mid vowel. Mid vowels are permitted in non-initial syllables, via the multiple linking of an initial Aperture node, as discussed above. However, when a low *a* follows the initial mid, vowel harmony is not possible; this is due to undominated Ident(lo). Low vowels cannot share the Aperture node of the initial vowel without raising to mid, a violation of Ident(lo). The Aperture node of the initial vowel cannot spread beyond an intervening low vowel, due to the familiar prohibition on line crossing (Goldsmith 1976). Mid vowels are therefore ruled out following low *a*; the unmarked [+high] value emerges in this context, by virtue of the ranking *Mid ≫ *High.

6 On the inadequacy of featural alignment analyses

Most prior analyses of vowel harmony in Optimality Theory have appealed to feature alignment constraints (extending the Generalised Alignment framework of McCarthy & Prince 1993a) to account for positional anchoring and spreading of harmonic features (see Kirchner

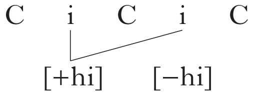
1993, Akinlabi 1994, Pulleyblank 1994, Cole & Kisseberth 1995, Ringen & Vago 1995a, b for a representative sample of feature alignment analyses). I will demonstrate that the Shona facts are not amenable to an analysis which relies on alignment.[31]

Any alignment analysis of Shona height harmony must incorporate the independently motivated markedness constraints *Mid and *High, with the ranking *Mid ≫ *High. (This ranking is required to account for cross-linguistic generalisations concerning inventory structure, and to relate these generalisations to the distribution of height in Shona.) Furthermore, faithfulness constraints on [high] must be dominated by the alignment constraints in order to account for harmonic spreading. Were faithfulness to [high] to dominate Align(hi), faithful parsing of the input would take precedence over vowel harmony. In the following discussion, I will consider analyses framed in the context of a *Gen* function which observes containment (Prince & Smolensky 1993), as well as approaches which assume correspondence. In neither view of *Gen* is an alignment analysis of harmony attractive.

6.1 Containment and alignment

Previous Optimality Theory analyses of vowel harmony making use of alignment have been couched in terms of containment; input feature specifications which are not parsed in output candidates are nevertheless present in output representations. For example, given a /CiCeC/ input with spreading of the initial [+high] specification, the resulting [CiCiC] output representation is as in (41):

(41)



The persistence of unparsed specifications plays a crucial role in alignment-based analyses of Shona, as the following discussion will make clear.

The minimal set of constraints required to account for Shona harmony will include the independently motivated markedness constraints *Mid and *High, as well as the containment-based faithfulness constraint Parse(hi). Because mid vowels do surface in Shona, Parse(hi) must dominate *Mid; as argued above, *Mid dominates *High. This yields the ranking in (42):

(42) Parse(hi) ≫ *Mid ≫ *High

The root-initial anchoring of harmonic features, as well as the homogeneity of vowel height in non-low verbs, is accounted for in this analysis by a high-ranking Align(hi) constraint:

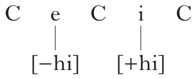
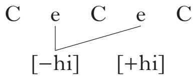
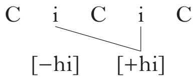
(43) Align(hi): Align([high], Root-L)
(Every parsed [high] specification must be aligned with the left edge of a root.)

Because any non-initial input specifications are obliterated, replaced by the correctly aligned initial [high] specification, Align(hi) must dominate Parse(hi). The ranking in (44) results:

(44) Align(hi) ≫ Parse(hi) ≫ *Mid ≫ *High

Setting aside the question of low vowel opacity and the complex [CeCaCiC], there are four surface patterns of height distribution which must be generated in the analysis: [CeCeC] (*[CeCiC]), [CiCiC] (*[CiCeC]), [CaCiC] (*[CaCeC]) and [CeC]. Consider first the hypothetical input /CeCiC/:

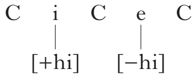
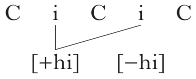
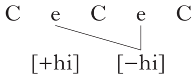
(45) Align(hi) *with containment*

/CeCiC/	Align(hi)	Parse	*Mid	*High
a.  C e C i C [−hi] [+hi]	*!		*	*
☞ b.  C e C e C [−hi] [+hi]		*	*	
c.  C i C i C [−hi] [+hi]	*!	*		*

The occurring form (45b) is optimal *only* if the unparsed [−high] specification from the initial vowel is referred to in the computation of alignment violations incurred by (45c). Were this not the case, the *Mid violation assessed for (45b) would be sufficient to rule this candidate out, incorrectly yielding [CiCiC] as the output.

Given this assumption about unparsed features and the computation of Align(hi) violations, the results for /CiCeC/ inputs are similar:

(46) *Height harmony with a /CiCeC/ input*

/CiCeC/	Align(hi)	Parse	*Mid	*High
a.  C i C e C [+hi] [−hi]	*!		*	*
☞ b.  C i C i C [+hi] [−hi]		*		*
c.  C e C e C [+hi] [−hi]	*!	*	*	

Here, the correct result is again the actually occurring form (46b); each of the other candidates violates Align(hi), under the assumption that the unparsed [+high] specification in (46c) is misaligning.

The next case to be considered is that of a hypothetical /CaCeC/ input, which must surface as a [CaCiC] output. (Recall that surface *a…e* sequences are unattested.) The constraint system outlined for (45) and (46) fails here, as (47) demonstrates:

(47) *Incorrect generation of* [CaCeC] *output*

/CaCeC/	Align(hi)	Parse	*Mid	*High
☞ a. C a C e C [+lo] [−hi][−lo] [−hi]	*		*	
b. C a C i C [+lo] [−hi][−lo] [+hi][−hi]	*	*!		*

Both candidates in (47) incur violations of Align(hi), as there is a [high] specification in each case not linked to the leftmost vowel in the root. Candidate (47b) also incurs a Parse(hi) violation, which is fatal. The non-occurring (47a) is incorrectly predicted to be the winner. The only means of circumventing this problem is to invoke a different ranking of *Mid and Parse(hi), such that *Mid ≫ Parse(hi). However, as argued above, this ranking is impossible for Shona, as it would result in the complete elimination of mid vowels in the language. This analysis, then, is inadequate.

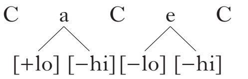
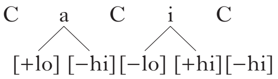
An alternative, still assuming containment, is the adoption of a dispersed Align(hi) constraint:[32]

(48) a. Align(−hi): Align([−high], Root-L)
(Every [−high] specification must be aligned with the left edge of a root.)
b. Align(+hi): Align([+high], Root-L)
(Every [+high] specification must be aligned with the left edge of a root.)

Parse(hi) and the markedness constraints *Mid and *High will still be called for in the grammar, as faithfulness and segmental markedness must be taken into account.

Recall that the generic Align(hi) analysis sketched above could not generate the correct output in the case of a /CaCeC/ input. Because the [high] specifications of [CaCiC] and [CaCeC] were equally misaligned, the decision fell to the faithfulness constraint Parse(hi), which incorrectly ruled in favour of the [CaCeC] output. With two alignment constraints, it is possible to rank Align(−hi) over Align(+hi), meaning that a misaligned [−high] will be less harmonic than a misaligned [+high]. Consider tableau (49):

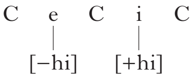
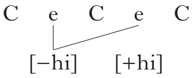
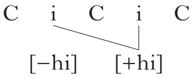
(49) *Dispersion of alignment;* /CaCeC/ *input*

/CaCeC/	Align(−hi)	Align(+hi)	Parse
a.  C a C e C [+lo] [−hi] [−lo] [−hi]	*		
☞ b.  C a C i C [+lo] [−hi] [−lo] [+hi] [−hi]		*	*

While both candidates incur alignment violations, the violation incurred by (49a) is more serious than that incurred by (49b), as Align(−hi) dominates Align(+hi) in this analysis. The optimal candidate is the actually occurring output form.[33]

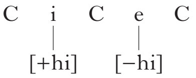
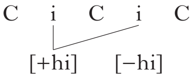
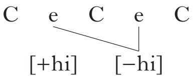
The cases of height harmony ([CiCiC] and [CeCeC]) also work out correctly, given the assumptions concerning the misaligning role of unparsed features discussed above. This is demonstrated in (50) and (51):

(50) *Dispersion of alignment;* /CeCiC/ *input*

/CeCiC/	Align(−hi)	Align(+hi)	Parse
a.  C e C i C [−hi] [+hi]		*!	
☞ b.  C e C e C [−hi] [+hi]			*
c.  C i C i C [−hi] [+hi]		*!	*

The optimal candidate, (50b), violates only the relatively low-ranking Parse(hi) constraint, while the other two candidates each violate Align(+hi).

(51) *Dispersion of alignment;* /CiCeC/ *input*

/CiCeC/	Align(−hi)	Align(+hi)	Parse
a.  C i C e C [+hi] [−hi]	*!		
☞ b.  C i C i C [+hi] [−hi]			*
c.  C e C e C [+hi] [−hi]	*!		*

Again, the optimal candidate incurs only a PARSE(hi) violation, while the other two relevant candidates each violate ALIGN(−hi).

The dispersion analysis seems to generate correctly all of the desired output forms. However, as in the generic ALIGN(hi) analysis sketched above, the presence of unparsed input specifications is absolutely essential in causing a violation of the relevant alignment constraint. Without this understanding of alignment violations, both the (b) and (c) candidates in (50) and (51) would tie in all respects other than *MID and *HIGH, predicting the less marked [CiCiC] output to be optimal in all cases. The reliance on a solely formal manipulation of this sort to encode the privileged nature of root-initial specifications is troubling. It is clear, however, that only this interpretation of alignment will provide a working account of Shona harmony, assuming containment. This has the consequence that the markedness constraints, which play a central role in determining inventory structure cross-linguistically, are completely redundant in the analysis of Shona harmony. The ranking *MID ≫ *HIGH, although recapitulated in ALIGN(−hi) ≫ ALIGN(+hi), does no work in determining the distribution of height features in Shona. This redundancy in the constraint system, while necessary to generate the correct surface forms, is otherwise unmotivated.

6.2 Correspondence and alignment

Given the dubious underpinnings of the containment-based analyses in the preceding section, the adoption of Correspondence Theory might seem an appealing alternative. However, alignment in Correspondence Theory fails entirely, precisely because the unparsed feature specifications preserved under containment are not available in the output candidates to be considered.

Because the preceding section established that an alignment analysis is possible with the adoption of two distinct ALIGN constraints, the same dispersion will be adopted for the discussion here. Assuming the correspondence implementation of faithfulness to be IDENT(hi), the following set of constraints will be required:

(52) *Correspondence-based constraints*

a. ALIGN(−hi): Align([−high], Root-L)
(Every [−high] specification must be aligned with the left edge of a root.)

b. ALIGN(+hi): Align([+high], Root-L)
(Every [+high] specification must be aligned with the left edge of a root.)

c. IDENT(hi): Correspondent segments in input and output have identical values for the feature [high].

d. *MID: *[−high, −low]

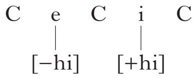
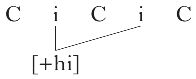
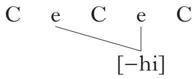
e. *HIGH: *[+high, −low]

As argued above, the harmonic behaviour of non-initial vowels must follow in an alignment analysis from the subordination of faithfulness constraints to alignment constraints:

(53) ALIGN(−hi) ≫ ALIGN(+hi) ≫ IDENT(hi)[34]

With this ranking in hand, consider the case of the /CeCiC/ input shown in (54):

(54) *Alignment with correspondence; /CeCiC/ input*

/CeCiC/	ALIGN(−hi)	ALIGN(+hi)	IDENT(hi)
a. 		*!	
☞ b. 			*
☞ c. 			*

Without reference to *MID and *HIGH, no choice between (54b) and (c) is possible. In the absence of unparsed feature specifications in the output representations, neither candidate is guilty of an alignment violation. Unfortunately, by allowing the decision between (54b) and (c) to fall to the markedness constraints, the less marked [CiCiC] will be chosen as optimal, because *MID ≫ *HIGH. Root-initial mid vowels are incorrectly predicted to be wiped out, due to markedness constraints; there can be no roots containing mid vowels at all in this language. The privileged licensing status of the root-initial syllable simply is not captured here, and it should be clear from the preceding sections that no account which assumes both correspondence and alignment will fare any better with Shona height harmony.

6.3 The case against feature alignment

The discussion above has established that an alignment analysis of Shona height harmony is possible only if correspondence is abandoned in favour of containment. Apart from the troubling problem that the general advantages of Correspondence Theory would have to be set aside (see McCarthy & Prince 1995), the adoption of the containment analysis presented above is clearly a questionable move. In order to achieve the effects of IDENT-σ_1(hi), the containment analysis must resort to an interpretation of alignment in which unparsed feature specifications cause violations. Furthermore, this analysis requires the replication of the markedness constraint hierarchy in the alignment constraints themselves. This redundancy, which is necessary in order to correctly generate the surface forms of Shona, renders the markedness constraints superfluous to the account of vowel harmony.

In contrast, the positional identity account provides a more direct route to the privileged licensing behaviour of initial syllables, and avoids placing the burden of explanation on formal manipulation. Additionally, this analysis rejects the redundancy of the alignment account: the preference for high, rather than mid, vowels in opaque contexts follows directly from the markedness constraint hierarchy *Mid ≫ *High, rather than from the recapitulation of this hierarchy elsewhere in the constraint system.

7 Typological predictions of position-sensitive faithfulness

One of the central tenets of Optimality Theory is that the grammars of different languages derive from different rankings of a universal set of constraints, rather than from the existence of distinct inventories of constraints. By permuting the rankings of a proposed subset of the constraint inventory, one can examine the typological predictions of the theory. Each of the available rankings should correspond to an attested language.

The interaction of markedness and faithfulness constraints is the focus of the current investigation. Because distinctive features and prominent positions are both potentially available as arguments for the Ident constraints, the full inventory of Ident constraints is potentially quite large. For practical reasons, I will set aside the full inventory and restrict the discussion to the specific constraints proposed above: Ident-σ_1(hi), Ident(hi), *Mid and *High.

Because the ranking *High ≫ *Mid has consequences for the structure of vowel inventories which do not seem to be borne out in attested languages (but see note 18), the ranking of these constraints is fixed at *Mid ≫ *High throughout. Further, as discussed in note 16, the ranking of Ident(hi) ≫ Ident-σ_1(hi) within a constraint subhierarchy does not generate results which are distinct from those produced by an alternative ranking of the subhierarchy, where Ident-σ_1(hi) ≫ Ident(hi). This latter specific ≫ general ranking is therefore taken to be invariant.

Taking these restrictions into account, there are six ranking permutations possible:

(55) Ident-σ_1(hi), Ident(hi) *and markedness ranking permutations*

	ranking	*result*
a.	*Mid ≫ Ident-σ_1(hi) ≫ Ident(hi) ≫ *High	no mid vowels
b.	*Mid ≫ *High ≫ Ident-σ_1(hi) ≫ Ident(hi)	no mid or high vowels
c.	*Mid ≫ Ident-σ_1(hi) ≫ *High ≫ Ident(hi)	no mid vowels; high vowels only initially; [+high] harmony possible
d.	Ident-σ_1(hi) ≫ *Mid ≫ Ident(hi) ≫ *High	mid vowels only initially; no harmony

e. Ident-σ_1(hi) $\gg$ Ident(hi) $\gg$ *Mid $\gg$ *High	mid and high vowels anywhere; no harmony
f. Ident-σ_1(hi) $\gg$ *Mid $\gg$ *High $\gg$ Ident(hi)	mid vowels initially; harmony (Shona)

The rankings in (55a–c) yield languages in which there are no mid vowels in the inventory; this follows from the ranking of *Mid above all Ident constraints. An input [$-$high] will not be faithfully reproduced in the optimal output, due to the undominated *Mid. (55a) is a language with only two vowel heights; any language with a three-vowel system (*a*, *i*, *u*) exemplifies this ranking. The ranking in (55b) characterises a language in which there are no non-low vowels at all.[35] The last example which lacks mid vowels is (55c), the most complex of these cases. The placement of *High between the two Ident constraints restricts contrastive high vowels to the initial syllable, and has the further consequence that [$+$high] is (potentially) harmonically active.[36]

The remaining rankings (55d–f) yield languages in which mid vowels are permissible in at least some positions. In (55d), mid vowels are permitted in initial syllables, thanks to the ranking Ident-σ_1(hi) $\gg$ *Mid. However, the subordination of *High to the general faithfulness constraint Ident(hi) rules out vowel harmony.[37] (55e) is a language in which the occurrence of mid and high vowels is entirely free; this is due to the ranking of all faithfulness constraints above all of the markedness constraints. Any value of [high] in the input will be faithfully reproduced in the output, regardless of position, and the low ranking of the markedness constraints obviates the need for shared feature specifications. There is no vowel harmony in a language such as (55e). Finally, the ranking in (55f) yields a language with initial mid vowels and vowel harmony; Shona is an exemplar of just this ranking.

As noted above, the typology predicted by the range of prominent positions which may serve as arguments of faithfulness constraints (including syllable onsets, stressed syllables and long vowels) extends considerably beyond the simple scenario sketched in (55). Documenting the extent to which the typological predictions of positional faithfulness are borne out constitutes an important line of future research.

8 Conclusions

In this analysis of Shona positional neutralisation and concomitant height harmony, the distribution of the feature [high] is argued to follow from the relative ranking of identity constraints and the markedness constraints *Mid and *High. The analysis represents an advance in the treatment of vowel harmony in two key respects. First, the privileged licensing status of the root-initial syllable is attributed not to a combination of positional underspecification and ordered rule application, but to the high-ranking faithfulness constraint IDENT-σ_1(hi) within an Optimality Theoretic grammar. IDENT-σ_1(hi) and other, parallel initial-syllable faithfulness constraints provide a formal means of encoding the prominence of root-initial syllables. This relativisation of featural identity to perceptually prominent positions allows the special status of these positions as the loci of phonological contrast, and as triggers and/or blockers of phonological processes to be captured directly. Alternative analyses, such as featural alignment, must resort to dubious formal manoeuvrings in order to account for the Shona data. Furthermore, the alignment analysis fails to make the connection between basic featural markedness and the distribution of vowel height.

A second innovation of the positional identity approach presented above is the absence of any type of constraint which compels vowel harmony or shared features. Multiple linking of [high] from left to right within a harmonic domain is the output configuration which best satisfies the ranking of markedness and faithfulness constraints in the Shona grammar. The apparent directionality of Shona harmony arises from the high ranking of IDENT-σ_1(hi); the height features of initial syllables cannot change, meaning that only vowels to the right may harmonise. Vowel harmony is not targeted by a spreading constraint, according to this analysis, but is simply a byproduct of constraint ranking. The extent to which markedness and faithfulness constraints can shoulder the load formerly carried by directional rules remains a provoking open question.

NOTES

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[1] Shona is a Bantu language spoken primarily in Zimbabwe. According to the Bantu classification system of Guthrie (1967), Shona belongs in Area S. This group also includes Zulu, Xhosa, Sotho, Tswana and Tsonga.

[2] See Haiman (1972) for an early discussion of markedness and the reduction of vowel contrasts in non-initial positions in Turkish. Goldsmith (1985) also connects the occurrence of marked vowels to prominent positions ('free' positions, in his terms). Steriade (1993, 1995) provides a general overview of positional neutralisation phenomena, recalling and amplifying upon the observations of Trubetzkoy (1939).

[3] In the literature cited here, the distinction between word-initial and root-initial is not systematically explored – in many, it is difficult to determine whether only unprefixed forms, or both prefixed and unprefixed words, were used as stimuli. The processing of prefixal morphology is an interesting and complex matter. See Hall (1992) for a useful summary and discussion of the issues.

[4] In many of the languages or language families listed in Table I, prefixation is rare, meaning that prosodic word initial and root-initial syllables often coincide.

However, in Shona and other Bantu languages which exhibit robust root-initial effects, prefixation is extensive and highly productive, indicating that the distinction between word-initial and root-initial must be maintained.

[5] Thanks to Juliette Blevins for drawing this example to my attention. A few of the Damin items in Hale (1973) show non-Lardil segments in non-initial syllables: *nh!unh!u* ‘dog’, *n!an!a* ‘wife’, *n!un!u* ‘water’. As these appear to be reduplicative forms, they are not likely to be genuine counterexamples to the restricted distribution of marked segments.

[6] Hume (1996: n. 11) notes that prefixal vowels in Leti *are* subject to phonological alternation, and therefore speculates that the relevant initial position which is resistant to change must be non-affixal. This suggests a root/affix asymmetry in faithfulness, a division proposed by McCarthy & Prince (1994b, 1995).

There is considerable evidence, both psycholinguistic and phonological, that the root/affix distinction has a status similar to the initial/non-initial asymmetry under discussion here. For discussion of the processing literature and relevant references, see Hall (1988, 1992) and Hawkins & Cutler (1988). Implementation of root *vs.* affix faithfulness constraints, as well as examples parallel to the initial/non-initial cases in (5), can be found in McCarthy & Prince (1994b, 1995), Alderete (1996), Urbanczyk (1996) and Beckman (in preparation).

[7] Failure of palatalisation in these cases cannot be attributed to a lack of adjacency between target and trigger, as shown by examples such as *iyasečʼɛnzwa* ‘it is being worked’ (< *seɓɛnza* ‘work!’) and *iyašuɲelelwa* ‘it is being preached’ (< *šumayela* ‘preach!’). See Beckman (1994) for further discussion.

[8] Parallel constraint dispersion must apply for other comparable asymmetries, including onset/coda (see Padgett 1995, to appear and Lombardi 1996 for details), stressed syllable/unstressed syllable (Beckman in preparation) and root/affix (see note 6).

[9] Unless the mid vowel is a separate Final Vowel morpheme /-e/, marking subjunctive, negative habitual or potential mood. Mood-marking morphemes are not subject to vowel harmony, and are not considered here in the statement of distributional generalisations. For additional discussion of the Final Vowels and the treatment of them in this analysis, see note 20.

[10] The majority of verb roots in Shona are CVC in shape, but polysyllabic roots are not uncommon. Some polysyllabic roots reflect derived root+extension combinations from an earlier stage of the language; such forms have been lexicalised to varying degrees in the synchronic grammar. Many other polysyllabic roots are unambiguously monomorphemic. I have not included in (8) polysyllables which are arguably synchronically derived from another, monosyllabic, Shona root by the addition of a vowel-containing suffix; though these forms are also governed by vowel harmony, the status of non-initial vowels as members of the root cannot be confirmed.

[11] Data sources are abbreviated as follows: D = Doke (1967), Fi = Fivaz (1970), F5 = Fortune (1955), F7 = Fortune (1967), H = Hannan (1981), M = Myers (1987). Data are given in the Standard Shona Orthography of Hannan (1981), though phonetic transcription is retained for the implosives and the velar nasal. The correspondence between orthography and pronunciation is generally very close. However, note that ⟨sv⟩ = labialised alveolar fricative [s^{w}], ⟨tsv⟩ = labialised alveolar affricate [ts^{w}], ⟨sh⟩ = voiceless palato-alveolar fricative [ʃ], ⟨ch⟩ = voiceless palato-alveolar affricate [ʧ] and ⟨v⟩ = voiced bilabial continuant [β] (described as a fricative by Fortune 1955, but as an approximant by Hannan 1981 and Pongweni 1990). Vowel length (which is non-contrastive and appears only in the penultimate syllable, as a reflex of stress) and tone are omitted throughout.

Not all of these sources focus on the Zezuru dialect, but all of the roots cited are found in Zezuru, according to Hannan (1981).

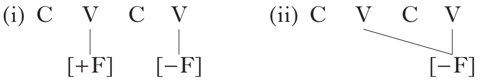
[12] Dale (1972) indicates that the first vowel of the reversive extension is a full copy of the final stem vowel: *-Vnur/-Vnor*. For example, *namanura* ‘unstick’, *petenura*

'unfold', *mono̱nora* 'uncoil'. This form of the extension is synchronically the most productive (Scott Myers personal communication).

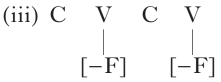
[13] Earlier work in generative phonology also attempts to avoid the Duplication Problem. For one proposal, see Ringen (1975).

[14] Additional correspondence constraints are proposed and defined in McCarthy & Prince (1995).

[15] I follow McCarthy & Prince (1995) in adopting the segmentally mediated Ident approach to featural faithfulness, though it is possible that features, in addition to segments, are in correspondence (as McCarthy & Prince 1995: 265 themselves suggest). The segment-based assessment of featural faithfulness obviates the need for various constraints on the recoverability of association lines which have been proposed in earlier OT work. (For example, see Pulleyblank 1994 and Itô *et al*. 1995.) If the input value (i) of a feature [F] is changed in an output candidate by virtue of the spread of a different input specification (ii), a violation of Ident(F) will be incurred:



Ident(F) is violated equally by simply changing the input specification on the initial vowel from + to −, as in (iii):



The segmental character of Ident constraints does not distinguish between (ii) and (iii). In the absence of phonological evidence that the output scenarios represented in (ii) and (iii) are discriminable results of altering the input (i), this seems a desirable result. However, see Myers (1996) for arguments that association lines are in correspondence.

[16] It seems desirable, for reasons of learnability, that the ranking between positional and context-free faithfulness constraints be fixed in Universal Grammar as in (17). Eric Baković (personal communication) has pointed out that Ident-σ_1(hi) can be active when dominated by Ident(hi), just in case both it and the context-free Ident constraint are dominated by some third constraint (such as the OCP), which forces output unfaithfulness. In such a case, the optimal candidate must be unfaithful in order to satisfy the OCP, meaning that an Ident(hi) violation will be incurred. The candidate which violates only Ident(hi), but not Ident-σ_1(hi), will be more harmonic than a candidate which violates both constraints:

(i)

/i…i/	OCP	Ident(hi)	Ident-σ_1(hi)
a. i…i	*!		
☞ b. i…e		*	
c. e…i		*	*!

However, the same results obtain if the positional ≫ context-free ranking of (17) is maintained:

(ii)

/i…i/	OCP	Ident-σ_1(hi)	Ident(hi)
a. i…i	*!		
☞ b. i…e			*
c. e…i		*!	*

In fact, for any possible ranking permutation of the three constraints in which Ident(hi) ≫ Ident-σ_1(hi), there is an another permutation in which Ident-σ_1(hi)

≫ Ident(hi) that will converge on the same optimal output candidate. Given this non-distinctness of results, there is no reason to assume free ranking of the positional and context-free constraints; further, if the ranking is fixed in UG as in (17), the problem of learning constraint rankings in the acquisition process will be considerably simplified. (But see Lombardi 1996 for arguments that the context-free ≫ positional ranking is required to account for the phonology of voice assimilation in Swedish.)

[17] The relative markedness of high and low vowels is not clear. Jakobson (1941) and Greenberg (1966) both propose an $a > i > u$ implicational hierarchy, with the low vowel implied by the high front vowel. However, Disner (1984) suggests a hierarchy of $\{i, a\} > \{e, o\} > u$, based on the frequency of missing vowels in the 43 defective vowel systems in the UPSID inventory; here there is no implicational relationship between the high front and low vowels. Also, both high and low vowels are found as default segments cross-linguistically. (For example, *a* is the epenthetic vowel in Axininca Campa (Payne 1981) and Makkan Arabic (Abu-Mansour 1987), while high vowels are epenthetic or default segments in a variety of languages, including Yoruba (Pulleyblank 1988), Zulu (Beckman 1992), Nancowry (Radhakrishnan 1981) and various Arabic dialects (Itô 1989).) Given this indeterminacy, it seems likely that the ranking of *High and *Low must be subject to cross-linguistic variation.

[18] The universal dominance hierarchy in (19b) predicts that there cannot be vowel inventories which contain mid vowels without high vowels. Mid vowels are present in an inventory if Ident(hi) ≫ *Mid, while high vowels are missing only if *High ≫ Ident(hi). Putting these subhierarchies together in a total ordering, we have *High ≫ Ident(hi) ≫ *Mid, but this is contradicted by the proposed universal ranking in (19b), *Mid ≫ *High. In the 317-language UPSID inventory surveyed in Maddieson (1984), there is one language, Amuesha (UPSID #824), which contains only mid and low vowels: /e o a/.

(19b) also predicts that mid vowels should never be favoured as epenthetic vowels over either high or low vowels, as mid vowels are more marked than either of the other heights. (See McCarthy & Prince (1994a), Alderete *et al.* (1996), Urbanczyk (1996) for additional discussion of a markedness-based approach to default vocalism in OT.) However, epenthetic mid vowels are attested (though rare). Spanish, for example, has an epenthetic *e*.

The markedness hierarchy in (19b) is perhaps best viewed as a perceptual markedness hierarchy, with non-peripheral mid vowels being more marked than the peripheral high and low vowels. (See Steriade 1995 for a recent discussion of perceptually based vowel features.) Both the inventory pattern of Amuesha and the existence of epenthetic mid vowels might arise from a distinct markedness scale based on vowel sonority, with higher sonority vowels being less marked than low sonority vowels. The syllable peak markedness scale of Prince & Smolensky (1993) will serve to demonstrate: *Pk/i, *Pk/u ≫ *Pk/e, *Pk/o ≫ *Pk/a. The preference for mid, rather than high, vowels may arise from the interaction of this sonority-based scale with the perceptual scale of (19b): *Pk/i, *Pk/u ≫ *Mid ≫ *High. This ranking favours the perceptually more marked mid vowels over the less sonorous high vowels. The relative rarity of this pattern is a matter for further research.

[19] The distributional generalisations which apply to height features in Shona verbs apparently do not hold of Shona nouns; vowel height in nouns is contrastive outside of the root-initial syllable. This type of phonological asymmetry between nouns and verbs is found in many languages; examples include English (nouns may exhibit antepenultimate stress, due to final syllable extrametricality, but this option is not available in verbs; Hayes 1981), Warlpiri (nouns are immune to vowel harmony, while verbs undergo it; Nash 1980) and many Bantu languages in which nouns exhibit a wider range of tone contrasts than do verbs (e.g. CiYao (Tanzania; Odden 1995) and Shona (Zimbabwe; Myers 1996)). (An anonymous reviewer points out that in many Bantu languages in which verbs exhibit a reduced system of tonal contrasts, the contrast is available only in the root-initial syllable.) Similarly, in many Japanese dialects, the patterns of accent placement

are much more diverse and unpredictable in nouns than in verbs, where accent patterns tend to be limited and predictable (Smith 1996). Following the OT approach set out here, the resistance of nouns to phonological regularisation and reduction of contrastive information suggests that faithfulness in noun and verb roots may be assessed independently, with Faith-Noun ≫ Faith-Verb.

[20] An anonymous reviewer points out that a mid vowel *e may* appear after a low or high vowel *just in case* it is the mood-marking Final Vowel characteristic of Bantu verbal morphology. In Shona, final *-e* marks a number of different moods, including subjunctive, negative habitual and potential. There is clearly a tension between phonological regularisation and morphological contrast maintenance: if the height of the Final Vowel is neutralised in accord with high-ranking *Mid, mood distinctions in the verbal paradigm might be lost. This type of morphologically motivated resistance to phonological regularisation is not unique to Shona; for example, Warlpiri verbal inflections are immune to the normal vowel harmony process of the language; application of harmony would level a distinction between two tenses (Nash 1980). Similarly, prepausal epenthesis does not apply to Makkan Arabic nouns when the result would be homophonous with a related verb form (Abu-Mansour 1987: 206). The full characterisation of such phenomena would require more space than is available here; see Kenstowicz (1981, 1996), Burzio (1994), Benua (1995, in preparation), Beckman (1996) for discussion and analysis of related phenomena.

[21] As indicated in note 20, surface Shona verb forms include a mood-marking Final Vowel which is not subject to height harmony. The distributional generalisations under discussion hold of both underived roots and root + extension combinations, and the inputs in all tableaux are consistent with either type of form. For the sake of simplicity, final vowels are omitted throughout.

Also for the sake of simplicity, feature geometry is suppressed where not directly relevant to the point at hand.

[22] Output candidates in which no height is specified for a vowel are systematically omitted throughout; I assume (following Prince & Smolensky 1993, Smolensky 1993) that output underspecification is not an option. Thus, output candidates which completely lack any height feature specification are not supplied by *Gen*. Further, as low vowels are immune to feature-changing (due to the undominated Ident(lo)), no candidates with an unfaithful rendering of the initial low vowel are shown.

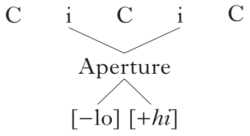
[23] In the case of roots, where there are no surface vowel height alternations, Lexicon Optimisation is sufficient to select an underlying representation. In the case of verbal extensions such as the applicative (*-ir*/*-er*) and neuter (*-ik*/*-ek*), the language learner's task is more difficult, as these forms do alternate. Regardless of which height is selected as underlying, the mapping from underlying form to output vocalism will incur faithfulness violations when the suffix is paired with roots of the opposite height value; there is no single most harmonic input–output mapping. Inkelas (1995) suggests that underspecification is the preferred option in such cases.

[24] Thanks to John McCarthy for discussion of this point.

[25] McCarthy & Prince (1994a) point out the feature-driven character of *F constraint evaluation. This plays a crucial role in Itô & Mester's (1994) analysis of Lardil, where place-linked codas in clusters such as *ŋk* escape the Coda Condition by virtue of the single place specification shared by both coda and onset.

[26] Unless we consider the representation in (i) below, where a [+high] specification has been inserted and the input specification of the initial vowel has been deleted:

(i)



Such a representation would fare as well as (30b) with respect to the constraint hierarchy, though it is intuitively less faithful to the input than (30b). Without Max(hi) and/or Dep(hi) constraints, the difference in faithfulness cannot be expressed; (i) satisfies Ident-σ_1(hi), just as (30b) does.

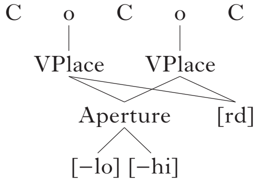
[27] Note that two specifications of [+high] will incur two violations of *High regardless of whether the specifications are underlying or are supplied by *Gen*. The failure of (32d) does not result from violation of Ident(hi), measuring faithfulness, but rather from violation of *High, which assesses markedness.

[28] See Kirchner (1993) and Padgett (1995) for related proposals.

[29] High-ranking *RoLo can effectively generate rounding harmony, without an active rounding harmony constraint in the grammar, provided that Ident(round) is low-ranking. For an alternative approach to rounding harmony, see Kaun (1995), who proposes a family of Extend(F) constraints; these constraints favour feature-spreading as a means of increasing perceptual salience.

[30] Two *RoLo violations are incurred even if there is only one [round] specification and one Aperture node shared by the two VPlace nodes, as in (i):

(i)



Markedness violations are assessed for that node which minimally dominates all the features in question, effectively requiring multiple linking of the dominant node in question. See Benua (in preparation) for an alternative proposal which favours multiple linking of class nodes, rather than of terminal features.

[31] See Kaun (1995: ch. 7) for additional arguments against harmony as featural alignment.

[32] An anonymous reviewer suggests that a dispersed Parse constraint will also correctly generate the desired forms, provided that Parse(+hi) ≫ *Mid ≫ Parse(−hi). This subhierarchy, when dominated by Align(hi), will account for the polysyllabic cases in (45)–(47), but will fail when faced with inputs such as /per-/ 'end'.

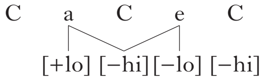
(i)

/per-/	Align(hi)	Parse(+hi)	*Mid	Parse(−hi)
a. p e r [−lo] [−hi]			*!	
☞ b. p i r [−lo] [+hi][−hi]				*

Here Align(hi) plays no role, and the ranking of *Mid over Parse(−hi) incorrectly rules in favour of the high vowel in candidate (b).

[33] Candidate (49b) is actually optimal only if we can additionally rule out the candidate in (i) below, where a single [−high] specification is shared by both vowels:

(i)



This candidate will satisfy Align(−hi), and fares better on Align(+hi) than does (49b). Whatever stipulation is required to rule out the structure in (i) will also be necessary to prohibit medial low vowels from propagating the spread of [−high] from initial mid vowels.

[34] The ranking of IDENT(hi) and the markedness constraints is actually irrelevant here. Any candidates which pass either alignment constraint will tie with respect to IDENT(hi), since one or the other of the input specifications must be removed in order to satisfy Alignment. This tie will throw the contest to the markedness constraints *MID and *HIGH, regardless of whether they are ranked above or below IDENT(hi). Crucially, though, the alignment constraints must dominate the markedness constraints.

[35] Such vowel systems do not occur, as Jakobson noted. Even languages which have only central vowels (e.g. many Caucasian languages) have a contrast in height. I assume that (55b) must therefore be excluded on independent grounds. An anonymous reviewer suggests that the ranking IDENT-σ_1(hi) $\gg$ *HIGH would effectively rule out (55b); the constraints on [low] would have to be in a similar relation (IDENT-σ_1(lo) $\gg$ *LOW) to rule out a language without low vowels. The issue of minimum inventory size and distinctiveness is a complex one, which will require additional study. See Flemming (1995) for proposals concerning this topic.

[36] The occurrence of [+high] harmony depends on the ranking of IDENT(lo) relative to the constraints on [high]. If IDENT(lo) is high-ranking, no harmony will occur; surface forms will be restricted to sequences of the form *i…a…a…* and *a…a…* However, if IDENT(lo) is crucially dominated, harmony will result.

This restricted role for contrastive vowel height would certainly result in a language with a limited range of lexical distinctiveness; perhaps such a language would be disfavoured on functional grounds. I know of no language with the height distribution described.

[37] At this writing, I know of no language with the *height* distributional restrictions of (55d), although its existence seems plausible. Examples may be generated by varying the positional argument in question. Icelandic, which has vowels of three heights in stressed syllables, is said to have only high or low vowels in unstressed positions. A simple substitution of $\acute{\sigma}$ for σ_1 in (55d) will generate the Icelandic system. (Thanks to Lisa Selkirk for pointing out the relevance of this example.)

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