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PHONOLOGY

ARTICLE

Metaphony, umlaut and !Xóõ A-raising

Julian Bradfield [1] and Shanti Ulfsbjornin [2]

[1]School of Informatics, University of Edinburgh, UK
[2]Department of Linguistics, Memorial University of Newfoundland, Canada

Corresponding author: Julian Bradfield; Email: jcb@inf.ed.ac.uk

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Abstract

Metaphony and umlaut are well-studied assimilations, and metaphony, in particular, has attracted a range of different analyses. This article casts both in the framework of Element Theory, but as quite distinct processes. We then study the complex assimilation pattern of the Khoisan language !Xóõ, between the first vowel of its bimoraic words and the second vowel, also affected by the consonants in the word. The most recent analysis, by Lionnet, argues that probabilistic and cumulative gradient effects are required to account for this process. We show that the process can be seen as formally a combination of umlaut and metaphony. Moreover, our analysis explains other assimilations and predicts a new assimilation, which is confirmed by recent data.

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1. Introduction

UMLAUT is generally seen as the assimilation of a vowel to a following vowel, often analysed as feature-spreading. METAPHONY is also so seen, but now the term usually applies to particular contexts, often with prosodic conditions. However, particularly in Romance languages, there are other analyses. In this article, we shall cast both processes in an Element Theory framework, where Romance metaphony appears as the result of licensing a 'low' feature, not spreading a 'high' feature. We then apply this formalism in the very different context of !Xóõ.

!Xóõ, !Xoon or Taa is a language of the Tuu (formerly Southern Khoisan) family,[1] famous for its world-beating array of click sounds. It displays a complex assimilation of the first vowel /a/ in a root to the second vowel and adjacent consonants. The primary published sources for !Xóõ are a phonological study (Traill 1985) and a dictionary (Traill 1994). Traill analyses this process as a raising assimilation to the second vowel, partially or fully blocked by certain consonants.

There are several other analyses of this phenomenon and of similar processes in other Khoisan languages (Nakagawa 2010; Miller 2011; Bradfield 2014). The most recent for !Xóõ is by Lionnet (2018), who conducts a very thorough examination of the sources, drawing out the extremely complex pattern exemplified in (1).

(1) *!Xóõ/ /a/-raising* (adapted from Lionnet 2018; examples from Traill 1985, 1994)

	Underlying	*Surface*	*Context type*	
a.	ǂabi 'young steenbok'	ǂɜbi	C^{+}__Bi	(non-blocking onset, medial b/m, final i)
b.	ǂai 'steenbok'	ǂii	C^{+}__i	(non-blocking onset, no medial, final i)
c.	ǂaẽ 'jaw'	ǂeẽ	C^{+}__e	(non-blocking onset, no medial, final e)
d.	!ali 'mane'	!ali	C^{-}__Li	(blocking onset, medial l/m/ɲ, final i)
e.	!ai 'stick handle'	!ɜi	C^{-}__i	(blocking onset, no medial, final i)

Lionnet (2018: 82) summarises his review of the data as in Table 1, where darker greys indicate more raising of /a/. The details are explained in §3.3.

Lionnet concludes that the pattern is probabilistic and gradient, reflecting the various triggering contexts involved in the raising. In his analysis, multiple triggering environments 'gang up' in 'phonological teamwork' to produce the pattern. For other proposed 'teamwork' phenomena, see Jäger & Rosenbach (2006), Lionnet (2017), Breiss (2020), and a precursor to the question in Flemming (2001).

In this study, we will unpick these conditions and show that the process of raising in !Xóõ is categorical and analysable as the combination of two processes, one umlaut-like and another metaphony-like. There are several interlocking factors: the combination of umlaut and metaphony, the language-specific natural classes of clicks and other consonants, the potential for blocking by certain consonants, and the syllable structure placement of nasals. These conspire to produce a gradient-looking pattern, which can nonetheless be broken down to individual co-articulatory, spreading and licensing conditions.

[1] 'Khoisan' remains in use as an ethnogeographic cover term of convenience, but the 'Khoisan' languages comprise the unrelated Khoe–Kwadi, Tuu and Kx'a families, and the isolates Hadza and Sandawe (Güldemann 2018a: 94–107).

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Table 1. *Summary of !Xóõ /a/-raising patterns (Lionnet 2018: 82).*

				Medial C								
	No medial C			J = j/ɟ			L = l/n/ɲ			B = b/m		
Onset	__i	__e	__a	__Ji	__Je	__Ja	__Li	__Le	__Li	__Bi	__Be	__Ba
ʔ__	i	e	a	–	–	–	–	–	–	–	–	a
C^{+}__	i	e	a	–	–	ɜ~i	ɜ~i	ɜʔ	a	ɜ	ɜʔ	a
C^{-}_	ɜ~e	ɜ~ɛ	a	–	a	a	a	a	a	a	a	a

In §2, we outline the distinction between what we call umlaut-type and metaphony-type processes and explain the featural framework of the article. In §3, we outline !Xóõ phonology and give the data we analyse. §4 lays out how we describe !Xóõ in Element Theory (ET). §5 presents the analysis of A-raising, including some perhaps unexpected correct predictions of our analysis, followed by a discussion of issues in §6. In §7, we analyse the usually ignored case of rounded first vowels: we correctly predict the raising, and also predict a hitherto overlooked unrounding assimilation. §8 discusses more general applications of our framework.

2. Metaphony and Element Theory

2.1. Metaphony

Metaphony covers a wide range of assimilatory phenomena that raise vowels in Romance languages (Calabrese 1985, 1998). Some consider it a morphophonological process or even deny that it is a phonological process at all (Pöchtrager & Kaye 2014). Others, however, situate it firmly in phonology (D'Alessandro & van Oostendorp 2016), even when the triggers are opaque or invisible (analysed as floating; Mascaró & Torres-Tamarit 2022).

A comparatively simple example of metaphony is shown in (2), where mid vowels are raised by following high vowels.

(2) *Metaphony in Foggia* (Valente 1975)

a.	ˈmoʃːa	ˈmuʃːu	'soft F.SG/M.SG'
b.	ˈkjena	ˈkjinu	'full F.SG/M.SG'
c.	ˈpɛte	ˈpiti	'foot SG/PL'
d.	ˈgrɔsːa	ˈgrusːu	'big F.SG/M.SG'

In the majority view that it is a phonological process, the aspects distinguishing metaphony from general vowel harmony vary between authors, as do the representational choices underlying the process. Some authors use [ATR] – although this is neither phonetically nor phonologically identical to the familiar African [ATR], they argue that there is phonetic grounding for this choice (Calabrese 2011: 2). For example, Calabrese (1998) finds metaphony distinctive in that [–ATR] targets are either diphthongised or tensed to [+ATR] or raised, or both, depending on the variety in question.

More traditionally, Walker (2005) primarily uses the feature [±high], and the distinctive property of metaphony is the stressed target vowel and its unstressed trigger. Her model is based on positional licensing and is driven by the motivation for the harmonic feature to sit in a prominent, that is stressed, position. She ties this together with stress-conditioned harmony in Servigliano (Le Marche) and stress-vowel delimited harmony in Ascrea (Lazio; Walker 2005: 918).

Canalis *et al.* (2024: 873) define *metaphony* as an 'umbrella term' for a group of related vowel-height-assimilatory processes such that: (a) the trigger is a word-final unstressed high vowel

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(typically a morphological marker); (b) the target is a vowel carrying word stress; and (c) stressed vowels, typically mid vowels, are raised. This formally treats metaphony as a type of vowel harmony with some coincidental shared characteristics. It then becomes a matter of judgement whether specific cases of vowel harmony are metaphony or not, such as when stress does not determine the target, as in Camuno (Cresci 2014: 63). Since this otherwise involves the same sets of alternations such an exclusion seems unsatisfactory.[2]

Mascaró (2016) limits his definition of metaphony as 'stress dependent harmony', either in the triggers or the targets.

Accepting the insight of this previous work, there is a more fundamental distinction between metaphony as a formal process and vowel harmony in general. This is particularly evident if we adopt an ET (Harris & Lindsey 1995) approach to vocalic representation. ET is a non-articulatory, privative system of features. Currently, it is most distinctive of Government/Strict CV approaches to phonology (Backley 2011), but it has important precursors in Dependency Phonology (Anderson & Jones 1974; Anderson & Ewen 1987), Natural Phonology (Donegan 1978) and Particle Theory (Schane 1984).

Given our adoption of ET, we group vowel harmonies based on the vowel quality of the alternations (triggers and targets). This leads us to a more restrictive and formal definition of metaphony, characterised by the loss of unlicensed features. This contrasts it sharply with other types of harmony via feature spreading. Those include umlaut, which has much in common with metaphony: it involves raising, and it typically proceeds from an unstressed high vowel trigger to a stressed vowel target, and it is often a morphological marker. However, the phonological mechanism underlying it is still one of feature spreading/sharing. Indeed, there are decades-old analyses which treat umlaut as the phonological exponent of a syntactic head in the form of a floating feature (see Hansson & Wiese 2024 for an overview).

2.2. Element Theory

ET recognises that the traditional vowel quadrilateral is perceptually more of a triangle (Lindsey 2017), as illustrated in Figure 1. The corners of the vowel triangle are characterised by distinctive spectral shapes (Harris & Lindsey 1995) shown in Figure 2.[3] Each shape has an 'autonomous interpretation' [i u a], but detailed acoustics is left to phonetic interpretation. (See Zahorian & Jagharghi 1993 for experimental evidence for spectral shape as a better cue than formants for vowel quality.) Thus each ELEMENT has an associated prototypical speech sound, while features may be abstract, articulatory or acoustic, and acoustic features such as [strident] describe broad characteristics, not actual sounds.

Unlike standard feature theory where mid vowels are all [−high, −low] and distinguished by other articulatory features, in ET (and all the precursors listed above), mid vowels are an amalgam of the corner spectral shapes, a combination of these primitive elements: |A.I| = [e/ɛ] and |A.U| = [o/ɔ], where |A.I| means |A| + |I|. Further subdivisions can be made by HEADEDNESS, a stronger presence of one of the elements, marked by underlining; for example, |A.I̲| = [e], |A̲.I| = [ɛ]. This is illustrated in Figure 3: in the left chart, we see the gradual deepening of the curve (roughly, decreasing F_1) and rightwards movement of the peak (increasing F_2) as we interpolate between [a] and [i] (the peak for [i] is off-chart). The right chart shows the interpolation between [a] and [u].

The phonetic interpretation of these element combinations is relatively free and language-specific, allowing, for example, the light-diphthong interpretation of certain vowels (perhaps only in computed forms; Kula 2008). Segments represented by an empty set may also have a language-specific phonetic

[2]Though naturally, a phonological study may be specifically interested in systems that involve only unstressed harmonic triggers and issues that arise from them (Walker 2005).

[3]Though intended schematically, the spectra here are genuine. The *x*-axes are linear from 100 Hz to 3,600 Hz, and the *y*-axes are from 20 dB to 90 dB. Vowels were recorded by the first author on a commercial voice recorder, speaking at a pitch of about 100 Hz, at CD quality. All are cardinal (in the speaker's best attempt), except for [a], which is a central low vowel [a̲]. Sounds were analysed and drawn with Praat (Boersma & Weenink 2022), using LPC with Burg's algorithm and 24 poles, and other settings standard.

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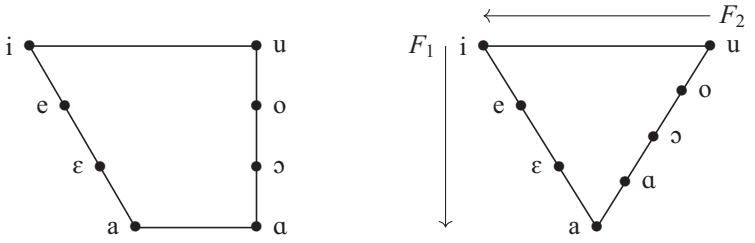


Figure 1. *Vowel quadrilateral* vs. *triangle.*

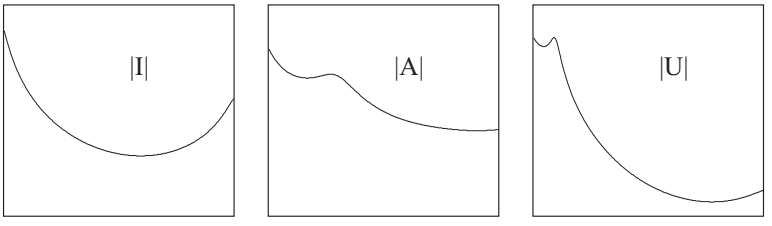


Figure 2. *Corner vowel spectra.*

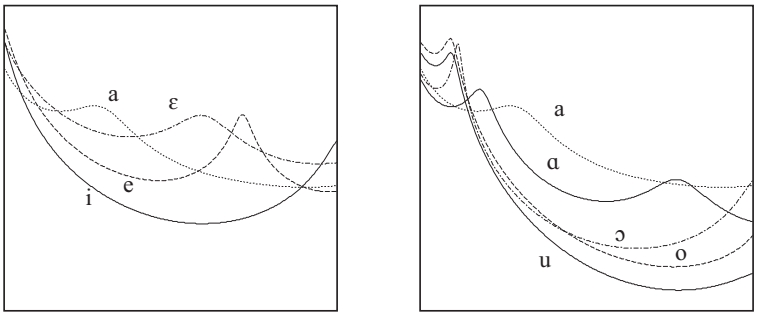


Figure 3. *Vowel spectra.*

interpretation, such as neutral vowels or schwas (Kaye 1990; Charette 1991). Some examples of such interpretations are shown in (3).

(3) *Some phonology-to-phonetics mappings in ET*

|A.I|	|A̲.I|	|A.U|	|A̲.U|	|∅|	|A|	|A̲|
e, je	ɛ, jɛ	o, ʷo	ɔ, ʷɔ	ɨ, ə	ə, ɐ, a	a, ɑ

The final elaboration of ET we employ is the FLOATING element, or variable element (van der Hulst 2018). A floating element, which we mark by grey shading as in |A|, is present in the underlying representation, but does not surface unless licensed by a phonological rule, for example, by a similar full element in an adjacent segment. Floating elements allow an apparently negative process (suppression of an |A| or [+low]) to be viewed as a positive process (licensing of the |A| in the unsuppressed case), as we demonstrate shortly.

2.3. Metaphony and umlaut in ET

Although the term *metaphony* was originally coined (as French *métaphonie*) as a translation of German *Umlaut*,[4] which ostensibly also involves raising of vowels in similar contexts, for example, [man] /

[4]See the online *Oxford English Dictionary,* s.v. *metaphony*: https://www.oed.com/dictionary/metaphony_n.

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[mɛn-lɪç] ‘man/manly’, [kuː] / [kyːə] ‘cow SG/PL’ (Lowenstamm 2012), the formal mechanisms which describe umlaut and metaphony are very different in ET.[5]

Its own particularities aside, umlaut is straightforward vowel harmony by feature spreading, or in ET by spreading of element |I|, which has the effect of fronting and raising target vowels.

However, in the dialects of Italy, the trigger of metaphony can be either /i/ or /u/, and either of these can raise either or both of /e o/ and /ɛ ɔ/, depending on the pattern. In ET, metaphony is analysed as the suppression of underlying features/elements where they are not licensed (Maiden 1991; Carvalho & Russo 2007a,b; Russo 2007, 2014; D’Alessandro & van Oostendorp 2016; van der Hulst 2018). For example, for the data from (2), the surface element content is shown in (4) for the first vowel.

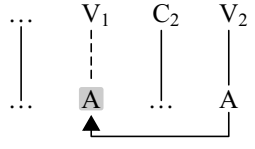
(4) *Subtractive analysis of metaphony in Foggia*

a.	ˈm**o**ʃːa	ˈm**u**ʃːu	‘soft F.SG/M.SG’
	|A.U|	|U|	
b.	ˈkj**e**na	ˈkj**i**nu	‘full F.SG/M.SG’
	|A.I|	|I|	
c.	ˈp**ɛ**te	ˈp**i**ti	‘foot SG/PL’
	|A.I|	|I|	
d.	ˈgr**ɔ**sːa	ˈgr**u**sːu	‘big F.SG/M.SG’
	|A.U|	|U|	

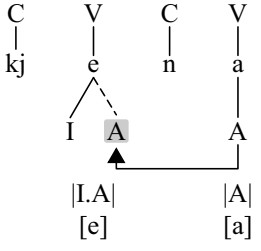
From these forms, one can analyse metaphony as A-licensing: |A| is underlyingly present in all forms, but only appears when licensed by an |A| in the final vowel.[6] Formally, the underlying form has floating |A|, which needs a licence to attach to a skeletal slot and be realised. The rule is shown diagrammatically in (5a), together with its application in (5b) and non-application in (5c). The notations are standard: the top row is the skeleton of C and V slots; the second row notes the segments associated with each slot; and the final row shows the elements associated. Solid association lines are underlying, while dashed associations are the result of phonological rules. Arrows indicate licensing relations.

(5) *Foggia A-licensing*

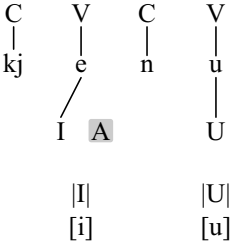
a. *Rule*



b. *Non-metaphonic /e…a/*



c. *Metaphonic /e…u/*



This models the contrastive presence of |A| in these nuclei, but also the alternation with its non-appearance in the metaphonic forms.

The Foggia example shows a simple example of the mechanism. Metaphonic systems show a dazzling array of complexity: interaction with morphology, opacity of the triggers, and possible interpretation with floating features (Mascaró & Torres-Tamarit 2022), or the role of stress in defining the locality of targets of metaphony (Walker 2011), or the non-application of metaphony to either lexical exceptions or where the process is restricted to close-mid vowels (e.g., Grado; Walker 2005). Space precludes going into these in any depth.

[5]In most analyses. Some, notably van der Hulst (2018), use licensing for all vowel harmony.

[6]For simplicity, we apply this only to the tonic vowel and treat final vowels as having |A|. Alternatively, they may have |A| licensed by final position.

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Directly relevant to us is Calabrese's (2011) claim that a weakness of the ET approach to metaphony, such as Maiden's (1991) A-demotion account, is the diphthongal output of the metaphony rules. Maiden (1991) proposes a special 'resolution'. More recent ET developments improve on the understanding of this phonology-to-phonetics mapping; and moreover, they open a space for the diphthongal outcome of metaphony, while providing an elegant account of its cross-linguistic variation and the trickiest aspect of its analysis, its chain-shifting nature.

In the Calvello examples in (6), we see a contrast between close and open mid vowels, which behave differently in metaphony. The outcome is also hard to model because of the distorted chain-shift [ɔ] → [ʷo], [o] → [u].

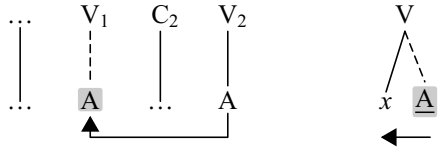
(6) *Calvello* (Calabrese 2011)

		SG	PL	
a.	M	sulu	suli	'alone'
	F	sola	sole	
b.	M	niru	niri	'black'
	F	nera	nere	
c.	M	ɣrʷossu	ɣrʷossi	'big'
	F	ɣrɔssa	ɣrɔsse	

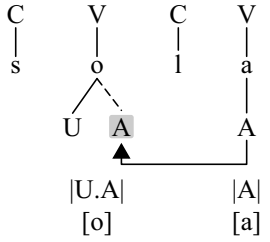
In ET, the open-mid vowels are usually interpreted as A-headed: /ɔ/ = |A.I|. However, as with the close-mid, we posit that in Calvello even the headed A is floating: |A.I|. The licensing rule is extended so that an unlicensed *headed* floating element still surfaces *unheaded*, and the head is transferred to the other element in the segment, as shown in (7) together with the application of the rule. (7b) and (7c) are the same as in Foggia, while in (7d), a floating headed |A| is licensed by the following |A|, and in (7e), a floating headed |A| 'self-licenses' *unheaded* |A| while also heading the other element |U|.

(7) *Calvello A-licensing*

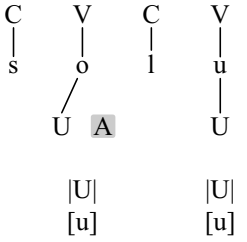
a. *Rule*



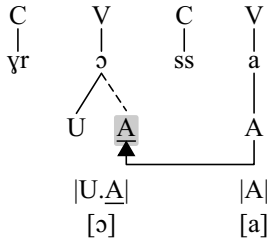
b. *Feminine /-a/*



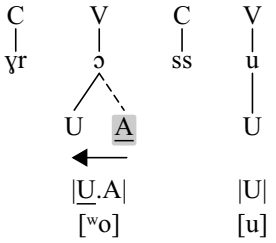
c. *Masculine /-u/*



d. *Feminine /-a/*



e. *Masculine /-u/*



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Systems like Calvello are quite phonetically transparent in reflecting the phonological shapes. The high-vowel element as the head is interpreted as the onset of a light diphthong.

However, ET is not rigidly grounded, and has 'slack' in the phonetic implementation of linguistic structure (Scheer 2019). This is accepted even in more standard theories. For instance, Calabrese (2011) acknowledges that the exact implementation of the diphthongisation is variable: [je jɛ iə] and [wo wɔ uə] (among others). Also, phonetic contours need not be phonological contours: light diphthongs and affricates are often single segments, as in Calvello /ʷo/ or English /ʧ/.

This slack in the phonetic implementation of phonological structures allows interpretative space for language variation, even when the phonological pattern is otherwise uniform. Thus a single phonological structure, such as |U̲.A|, may be interpreted differently in different languages, for example, as [ʷo] or [o].

Variation in the possible interpretation of headed structures is what makes other metaphonic systems so confounding. Take, for instance, the chain shift of Servigliano in (8).

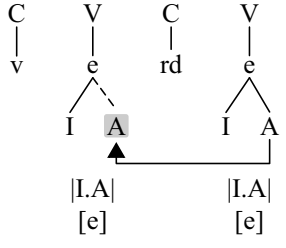
(8) *Servigliano* (Calabrese 2011)

	SG	PL	
a.	kurtu	kurti	'short M'
	korta	korte	'short F'
b.	fjore	fjuri	'flowers'
	verde	virdi	'green'
c.	pɛde	pedi	'foot'
	dɛnte	denti	'tooth'

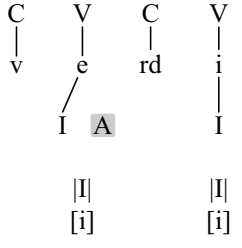
This can be interpreted just as Calvello, the only difference being the phonetic implementation of the non-A-headed structures, as shown in (9). The [e] from /e/ in *verde* is representationally distinct from the [e] derived from /ɛ/ of *pedi.* Likewise, we will see that the same phonetic surface vowel in !Xóõ can appear as the result of two different elemental forms. (Although in !Xóõ, there may indeed be a subtle phonetic difference.)

(9) *Servigliano A-licensing*

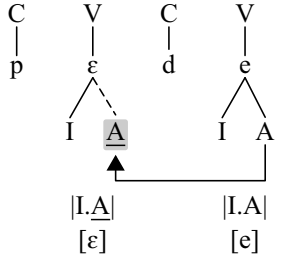
a. */e/ singular*



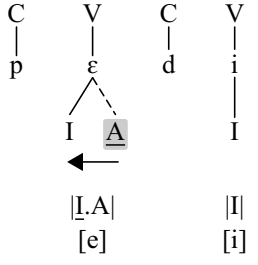
b. */e/ plural*



c. */ɛ/ singular*



d. */ɛ/ plural*

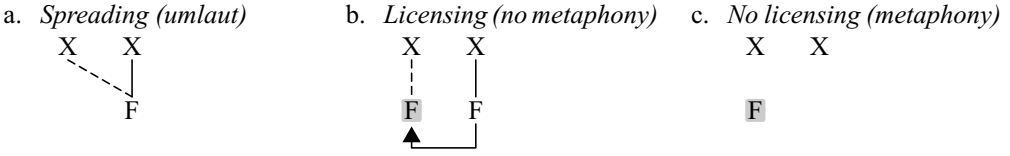


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More complicated cases involve the nature of the A-loss, in what combinations it is allowed, what is the phonetic outcome of the derived structure and so on. The details are found in the specific studies.

To summarise, vowel harmony may be the result of the additive process of spreading, or the subtractive process of (non-)licensing, as schematised in (10).

(10) *Umlaut* vs. *metaphony in ET*



The pattern from !Xóõ that we re-analyse in this article is complicated precisely because it involves both types of vowel harmony, which together give the appearance of a single complex gradient pattern of vowel raising (Lionnet 2018). We argue that part of this pattern is attributable to the same formal mechanism as metaphony in Romance.

3. !Xóõ phonology

!Xóõ is the endonym of some dialects of a Khoisan language, the sole living member of the Tuu family, studied by Traill (1985). Traill studied mainly a dialect from Lone Tree now called East !Xoon, with occasional reference to other dialects. Nowadays, the whole dialect cluster is generally called Taa ('person' in all dialects), and a pan-dialectal survey and dictionary is in progress by Christfried Naumann and colleagues, concentrating mainly on 'West !Xoon'. *!Xóõ* is now usually spelt *!Xoon* in the introduced orthography, but we retain the spelling of our primary sources. Further information on the language phylogeny may be found in Naumann (2014).

3.1. !Xóõ phonemes

We summarise the phonemic inventory of !Xóõ, and refer the reader to Bradfield (2014) for a full review of evidence and analyses up to 2014, and to Naumann (2016) for a detailed phonetic study of the Western !Xóõ inventory. We shall use phonemic notation in ‹guillemets› when citing !Xóõ forms, and reserve phoneme /slashes/ for explicitly phonemic discussion. We adopt Bradfield's symbol ʞ for a generic click.

The published primary sources are Traill (1985) and Traill (1994). We have been given, most generously, access to some of the ongoing dictionary of the Taa Documentation Project by Christfried Naumann *et al.* at the DOBES archive, and we cite this as TDP.

Lemmas for content words mostly have the bimoraic form $C_1V_1(C_2)V_2$. Here, C_1 is a pulmonic consonant, a simplex click, complex click–obstruent cluster or even an obstruent–obstruent cluster.

Prima facie, V_1 is usually /a o u/, with /e i/ arising (with a few exceptions) from the raising process that is our topic. V_1 can be further specified for breathiness, pharyngealisation and glottalisation. Current accounts favour describing V_1 as underspecified vowels /A U/ (or [−round], [+round]; originally proposed for ǀGui by Nakagawa 2006, 2010; extended across Khoisan by Güldemann & Nakagawa 2018); we follow this, with a slight modification.

C_2 is /j~ɻ l~r m n ɲ b/. V_2 is /a e i o u/ with possible nasalisation; or /m̩ n̩/, in which case C_2 is empty.

Function words and affixes are typically CV, with C simplex.

!Xóõ is not considered to have lexical stress, but impressionistically the first syllable is usually stronger than the second, and distributional analyses analyse the prosodic accent on the initial CV (Lionnet & Hyman 2018: 655–658). Thus the typical prosodic word is a heavy monosyllable CVV, a

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trochee CVCV or a dactyl CVCV-CV, a structure generally found in the Khoisan languages (Nakagawa *et al.* 2023), and one typical of Romance metaphony. The language is tonal, with high or low tones on each mora in the current analysis, and complex grammatical tonal concord rules; we mark tone, but it plays no role in this article.

There are five basic clicks: /ʘ ǀ ! ǂ ǁ/. Clicks may carry manners such as (pre-)voicing, aspiration, nasality, ejectivity, etc. Clicks also occur followed by glottal stop, glottal fricative or uvular stop, perhaps with ejectivity, aspiration or affrication. For example, in the East !Xóõ dialect of Traill (1985), the lemma for 'gnaw meat off a bone' is ‹ᵍǀqᵡ'ᶇ̀lè› (or ⟨gǀqx'ù'lè⟩ in modern cross-Khoisan orthography): the initial dental click is prevoiced, and the posterior uvular closure is held and then released ejectively with affrication, followed by a creaky vowel. There has been a long debate about whether these sounds are clusters or single phonemes: see Bradfield (2014) and Bennett (2020) for reviews. Most Khoisanists now prefer the cluster analysis; we adopt a compromise, having two root nodes attached to a single skeletal slot (cf. Bradfield 2014, 2018; Polgárdi 2014).

Pulmonic C_1 also ranges widely, with stops in five places of articulation /p t̪ ʦ k q/, with voicing, aspiration and/or ejectivity, and (for coronal and labial stops) combined with the same uvulars that can follow clicks; also fricatives /s f χ h/. For simplicity, the dental /t̪/ will just be written /t/.

3.2. The back vowel constraint

Khoisan languages all have some form of phonetic 'back vowel constraint' (BVC; Traill 1985; Miller-Ockhuizen 2000; Nakagawa 2006), informally expressed as: a back consonant is not followed by a front vowel [e i]. The definition of 'back' varies somewhat between languages, as does the strength of the constraint, from a tendency to a strict rule. In !Xóõ as described by Traill, the back consonants are the clicks [ʘ ! ǁ] and the velar and uvular non-clicks. For example, the form [ǀii] is licit, but *[!ii] is not.

3.3. 'A-raising'

The phenomenon we here discuss is traditionally known as 'A-raising'. It was introduced by Traill (1985) in the process of promoting the BVC from a phonetic constraint to a phonological constraint in !Xóõ. He observes that not only is [ǀii] licit, but *[ǀai] is not found; moreover, V_1 = [i e] is only found before the same V_2. Traill (1985: 90–91) thus proposes that V_1 is always underlyingly /a o u/ after any click, and when it surfaces as [e i], it does so by assimilation of /a/ to V_2.

Contrariwise, Miller (2011) on Juǀ'hoansi (a Kx'a language, so unrelated, but with a similar phenomenon) argues that instead underlying /i/ is lowered to [a] before low V_2. Nakagawa (2010) on Gǀui (of a third unrelated family, Khoe–Kwadi) suggests the intermediate view that V_1 is one of two archiphonemes /A U/, specified only for rounding, and filling in its other features from V_2. As remarked, this analysis is popular now among Khoisanists, and we adopt it, except that we use /O/ rather than /U/, as we analyse both back and front V_1 to have a default low height rather than a completely unspecified height.

Regardless of the analysis, what makes this process particularly interesting in !Xóõ is the detail of when the assimilation or in-filling happens. The description in Traill (1994) is as in (11):[7]

(11) *Traill's 'A-raising rule'*
First mora non-pharyngealised /a/ undergoes raising as follows:
   a. it is raised to [ɜ] when preceded by /t ǀ ǂ/ and followed by /i m n ɲ/, or when followed by /Ci/.
   b. It is raised to [i] when the second mora is just /i/, and [*not stated in the text but notated in the dictionary*] C_1 does not include an explicit uvular segment.
   c. After other consonants and immediately followed by /i e/, it raises to [æ].

[7] Traill uses 'rule' for his descriptive generalisations of phonological processes, couched in informal SPE-like terms.

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In a more detailed account, Traill (1985) describes the raised /a/ as varying over [ɜ – ɨ – æ – ɛ]. We use [ɜ] for all of these; the first author's observations from audio data suggest the variation is fairly free.

Traill does not discuss the case of V_2 = /e/, but in the dictionary entries themselves he notes /ae/ becoming [ee] in raising contexts.

In Traill's surviving recordings, the [æ] in (11c) is hard to distinguish from the raising described in (11a), and is predicted to be the same by the analysis of Bradfield (2014). We will not rely on it, but it turns out that our analysis can account for it as an automatic side-effect; see example (22).

Lionnet (2018) undertook a meticulous examination of Traill (1994), and observes that some words with explicit uvulars (namely ‹ǀqʼíí-sa ǀqʰíí ǀqʰéé ǀqéé›) are marked with full raising, contrary to (11b). However, since he wrote, the long-awaited revised dictionary (Traill 2018) has been posthumously published, and therein the first three words have been reassigned to the corresponding non-uvular segments /ǀʼ ǀʰ/. Moreover, the first author's examination of audio data for relevant words from TDP supports the original statement. The problem of ‹ǀqéé› 'Nama person' remains; this word also appears as ‹ǀqáé› in TDP, but unfortunately we do not have the audio. We stand by (11b) as stated, and suspect that ‹ǀqéé› may actually have been partially raised [ǀqæe].

Finally, (11a) does not list the alveolars as raising consonants. Like Lionnet (2018), we shall add these.[8]

Taking these observations into account, we restate 'A-raising' for the purposes of this article in (12), where (and henceforth) we write C^+ when C is either a click involving /ǀ ǂ/ or a dental/alveolar pulmonic, and C^- otherwise. (Lionnet 2018 writes $C_{[+]}$, $C_{[-]}$.) We write $C^{ǫ}$ to mean C has an explicit uvular, as /ǀq ǀqʰ ǀqʼ ǀqχʼ ǀχ/ have, and $C^{!ǫ}$ for C with no explicit uvular.

(12) *A-raising*

a. In a word $C_1^+V_1(C_2)V_2$, non-pharyngealised V_1 = /A/ is raised to [ɜ] when V_2 = /i ṃ ṇ/ or C_2 = /ɲ/.

b. In a word $C^{+!ǫ}V_1V_2$ where non-pharyngealised V_1 = /A/ and V_2 = /i e/, V_1 assimilates fully to V_2.

c. In a word $C_1^-V_1V_2$, where non-pharyngealised V_1 = /A/ and V_2 = /i e/, V_1 is raised to [ɜ].

We shall see that even this description is probably not entirely accurate, according to Traill's own data – because he did not consider the archiphonemic idea, he did not consider that /i/ should *never* appear as underlying V_1.

4. Elements for !Xóõ

We aim to show that A-raising involves metaphony according to the formal ET analysis sketched in §2. We therefore require an element analysis for !Xóõ.

There have been two ET presentations of !Xóõ. Bradfield (2018), who was mainly concerned with extending the 'concurrent' analysis of Bradfield (2014) to ET, assumes a rich set of elements. The main idea we adopt from there is the unusual suggestion, justified by both phonology and allomorphy, that the consonants we designate C^+ (thus including /ǀ ǂ/ and /t̪/) carry the |I| element, just as Bradfield (2014) posits that they carry the feature [+high]. Complex onsets such as /ǀq/ are handled by having two place nodes. Polgárdi (2014) also takes that approach, but differs in the details. We do the same.

[8] Traill (1985) describes the /ʦ …/ series as 'laminal alveolar affricates', which would not normally be 'back'. Moreover, there are fully raised words such as ‹ʦɛ̨ɛ̃› 'be raised up', ‹ʤi̤i̤› 'boil', ‹ʦʰéè› '[name]', ‹ʦʰíí› 'iron'. Traill would have viewed these as having underlying V_1 = /i e/, whereas the underspecified V_1 approach requires them to be the result of raising. Thus we consider alveolars to be raising. However, Lionnet notes that in Traill (1994) the word ‹sání› is noted with full raising [sini], which is not predicted by (12). There seems no way to explain this other than as an exception. Unfortunately, there is no suitable recording. In the Western dialect represented in TDP, ‹sa̧ní› can be heard as [sa̧ni].

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4.1. Skeletal tier

We adopt a framework that distinguishes consonants and vowels by C or V slots at the skeletal tier. We are not here concerned with arguments about Strict CV phonology (Lowenstamm 1996; Scheer 2004), but will interpret complex onsets (/|qʰ/ etc.) as attached to a single C slot, and mark C_2 in the skeleton even when empty.

Each slot has one or two place nodes and a manner node, each containing elements. We are generally not concerned with the manner nodes, so we elide them from our representations.

4.2. Elements for consonants

We adopt a headed version of ET with few elements, mostly following Backley (2011). Sounds can contain multiple sets of place elements, used for example in English long vowels and diphthongs; we use the same technique for click consonants. We assign elements for places of articulation of simple consonants as in (13).

(13) *Place elements for pulmonic consonants*

p	t	ʦ	ʝ/ɲ	k	q	h	ʔ
|U|	|I|	|I|	|I|	|U.A|	|U.A|	|∅|	|∅|

Here, |U| is found in both labials and velars, but is headed in labials. Similarly, |I| is found headed in palatals, but also occurs in coronals that pattern with palatals. !Xóõ is a little unusual in that its dental/alveolar stops pattern with palatals.[9] Additional evidence for |I| in dentals is that the particle ‹kV› has a concordial form that should be ‹ki›, but is often realised as ‹ti›, by assimilation to |I|. Velars *per* Backley (2011) are just |U|, but for reasons that will be clear from analysis to follow (see also §6.1.2), in !Xóõ they contain |A|; uvulars are distinguished by heading the |A|. (See Bellem 2008 for other approaches to uvulars in ET.)

If C_1 always occupies one C-slot, we must represent clicks, click–obstruent clusters (e.g., /|q'/) and obstruent–obstruent clusters (e.g., /tqχ'/) in a single slot. Adapting ideas from Bradfield (2018) and Polgárdi (2014), we assume that clicks and clusters have two place nodes, notated as, for example, |A;I|. Clicks are distinguished by velarity |U| in the first slot. The clusters have the click or first obstruent elements in the first slot, and the second obstruent elements in the second. The plain click first nodes contain either |I| for the raising clicks or |A| for the non-raising clicks, with headedness employed as for pulmonics.

The simplex clicks have |U| in the second place node, corresponding to the velarity of the posterior closure release, as in (14).

(14) *Place elements for simplex clicks*

ʘ	ǀ	ǃ	ǂ	ǁ
|U.A;U|	|I.U;U|	|U.A;U|	|I.U;U|	|U.A;U|

The clicks with uvular accompaniments have |U.A| in the second node, corresponding to the uvular obstruent.

The /ʞh ʞʔ/ clicks have an empty second place node: for example, /|h/ is |I.U;∅|. The rationale is that these clicks do not have an audible posterior release transition: the click is followed in /ʞʔ/ by a short silence before the glottal release, and in /ʞh/ by crescendo aspiration (and, according to Ladefoged & Traill 1984, even has ingressive nasal airflow to ensure there is no air pressure to make an audible release).

Elements for manner, shown in (15), are mostly standard in the style of Backley (2011). The voiced versions have an additional |L|.

[9] Cf. Australian languages, where (laminal) dentals pattern with palatals, though there, (apical) alveolars do not (Backley 2011: 90).

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(15) *Manner elements for voiceless clicks*

ʞ	ʞʰ	ʞʼ	ᵑ̊ʞ̊	ᵑʞ	ᵑ̊ʞ	ʞq	ʞqʰ	ʞqʼ	ʞqᵡʼ	ʞχ	ʞh	ʞʔ
|ʔ|	|ʔ.H|	|ʔ|	|L.H|	|L|	|ʔ.L|	|ʔ|	|ʔ.H|	|ʔ|	|ʔ.H|	|ʔ.H|	|ʔ.H|	|ʔ|

Thus, for example, /ǂqʰ/ has place nodes |I.U;U.A| and manner node |ʔ.H|.

4.3. Elements for full vowels

The basic five vowels /i e a o u/ that occur in V_2 position and in monomoraic words are represented standardly as |I|, |A.I|, |A|, |A.U|, |U|, with the use of headed elements allowing lower allophones to be represented unheaded. Manner for breathy and creaky vowels is also standard: add |H| and |ʔ|.

!Xóõ also has pharyngealised vowels, and 'strident' (epiglottalised) vowels. The latter are arguably phonologically breathy pharyngealised. There is no agreed representation in ET; since we operate with distinct place and manner nodes, we can stipulate that |A| in a manner node represents pharyngealisation (for more on A and pharyngealisation, see Bellem 2008 and Faust 2017).

Our analysis entails that the sound [ɜ] is sometimes a phonetic realisation of an empty V-slot and alternates with [ɨ], following Lionnet's (2018) observation of when [ɜ] has [ɨ] as an allophone. However, in other forms and contexts, [ɜ] is an allophone of a V-slot containing |A.I|, and it alternates with [ɛ æ e] and even [ɨ]. Hence, we stipulate that the empty vowel |∅| is realised as [ɜ].

The moraic nasals /n̩ ŋ̩/ occupy V_2 position and (according to Traill) both trigger raising after $C_1^{\dagger}$. /n̩/ is dental, and so should be |I.L.ʔ|. However, Traill (1985) records that unlike the other dentals, it has an apical rather than laminal articulation, and auditorily it has 'A-resonance' with an [ɜ]-like quality rather than [i]-like. We suggest that it is rather |I.A.L.ʔ|. /ŋ̩/ is simply |U.L.ʔ|.

4.4. Elements for V_1

As described in §3.1, a popular and attractive analysis of V_1 in Khoisan is as an underspecified vowel /A O/ carrying only a rounding value, or in ET terms presence or absence of |U|. Since the height of V_1 in bimoraic words is predictable from context, ascribing any other features than rounding to its underlying form is necessarily stipulative. However, [a] is by far the most common vowel in the language, with around half the lexicon having V_1 = [a]. We choose on *sprachgefühlig* grounds to specify /A/ with floating |A| to acknowledge this, and so allow our metaphonic analysis of 'back' consonants enabling the underlying [a] quality. According we specify /O/ as |A.U|.

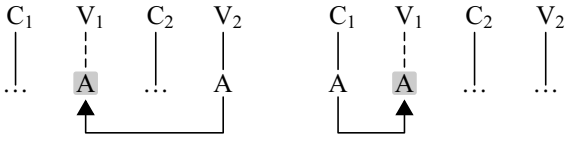
5. Analysis

We present a sequence of licensing rules which, when combined, account for the A-raising rule, and then illustrate them on examples.

5.1. Rules

The first rule, in (16), licenses the floating |A| in V_1 if there is |A| in either C_1 or V_2. (There is no C_2 containing |A|.) This rule is parallel to the formal description of metaphony in §2, with the addition of A-licensing from C_1. As in many instances of metaphony, V_1 corresponds to the head of the foot, and its |A| can be licensed by the foot dependent, if we accept the idea of !Xóõ as a basically trochaic language (§3.1).

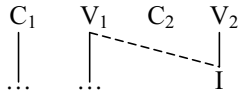
(16) *A-licensing*



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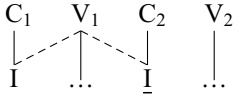
The second rule, in (17), describes spreading of (headed or unheaded) |I| from V_2, that is, the 'raising'. The licensing element may be headed, and then heads its licensee. However, in our analysis, this only applies when there is no intervening C_2.[10] This rule parallels our definition of umlaut in (10a).

(17) *Vowel I-spreading*



The final rule, in (18), deals with the particular case of palatal C_2, which allows raising even when V_2 is /a/.[11] It is best seen as a 'plateau effect', where C_1 and C_2 form an assimilatory domain for the element I, affecting the interpolated V_1. This rule only applies when the rightwards element is headed.[12]

(18) *Consonant I-spreading*



Plateau effects are seen in both tonal and segmental phonological processes, though they are commoner in tonal ones (Hyman 2011: 500–501). The ban on HLH and HØH is a constraint found in several languages (Cahill 2007, reported in Hyman 2011), so much so that Yip (2002: 137) gives it a constraint *Trough.

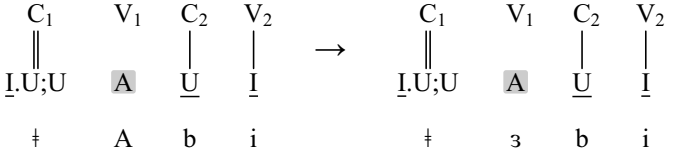
Plateau effects are also reported in vowel harmony. Hyman (2011: 218–219) highlights Yaka, which lowers /i/ exclusively when bounded by mid vowels on both sides: e/o…i…e/o → e/o…e…e/o. And in Woleaian (Howard 1972; Nevins 2010), an underspecified vowel /a/ only raises to /e/ when surrounded by a [+high] donor on each side; for example, i…a…i → i…e…i. This example shows a plateau effect for the same feature |I| as we propose for !Xóõ.

5.2. Examples

We present examples discussed by Lionnet (2018) and given in (1), which are all drawn from Traill's dictionary or text. The underlying form is on the left, and the form computed by the rules in §5.1 on the right. Unassociated floating elements are not realised in the surface form. As a notational convention, a double line represents a bundle of association lines from the slot to all the elements listed, while a single line links only to the specific element it is aimed at. Recall that the notation |A.U;U| represents a complex consonant with two place nodes.

No rules operate in (19), so V_1 surfaces with an empty place node, resulting in [ɜ]:

(19) ‹ǂábí› /ǂÁbí/ [ǂɜ́bí] 'young steenbok'



[10] Recall that we explicitly mark the absent C_2 by an empty slot, in Strict CV style.

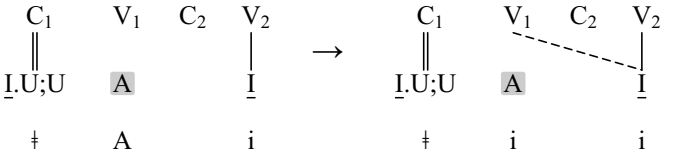
[11] There is one entry in Traill (1994), ‹tʰìà/tʰàjà› 'to work metal', which appears to show the otherwise unrecorded sequence [ia] as a realisation of /aja/. Explaining this would require another rule to block A-licensing, which would be an optional rule. One entry with no other support is perhaps rather weak to be worth the effort here.

[12] In ET, headed elements often have stronger effects. This rule is, as reviewers note, somewhat *ad hoc.* There is no evidence for it in TDP.

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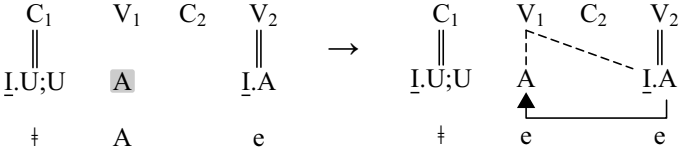
In (20), I-spreading operates, but the |A| remains unlicensed, resulting in a fully raised [i]:

(20) ‹ǂìì› /ǂÀì/ [ǂìì] ‘steenbok’



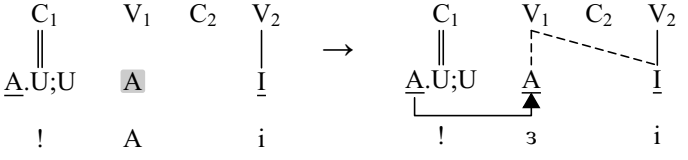
In (21), I-spreading and A-licensing both operate, giving |A.I| [e] for V_1:

(21) ‹ǂéɛ̀› /ǂÁɛ̀/ ‹ǂéɛ̀› ‘jaw’



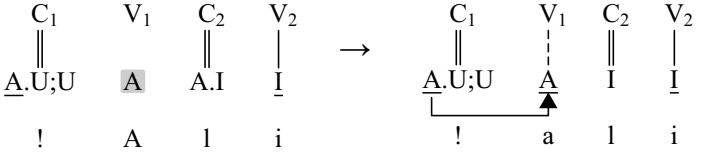
(22) is similar, but here |A| is licensed by the initial back click; the heading of the licensor transfers to the licensee, giving |A.I|, a more peripheral [ɜ], accounting for the [æ] from Traill’s rule in (11c). This also covers the case of front clicks with uvular accompaniments.

(22) ‹!áì› /!Áì/ [!ɜ́ì] ‘stick handle’



In (23), the initial back click licenses |A|, but there is no I-spreading, so /A/ is realised as its default form [a]:

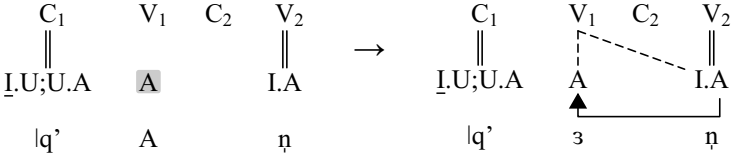
(23) ‹!álí› /!Álí/ [!álí] ‘mane’



5.3. Moraic nasals

Recall that !Xóõ has moraic, tone-bearing nasals ‹m̩ n̩›, which can take V_2 position (and in fact also V_1 in a couple of very common grammatical words). In §4.3, we argued for ascribing the elements |A.I| to /n̩/, making it phonologically a blend of dental and alveolar. We can now reveal the real motivation: /n̩/ acts as a raising vowel like /e/, but does not produce full raising as /i/ does. If it has |A.I|, then the following example from Traill (1985) is correctly predicted:

(24) ‹ǀq’àn̩› /ǀq’Àn̩/ [ǀq’ɜn̩] ‘small’



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In (24), the |A| of the moraic nasal licenses the floating |A| in V_1 by (16), but also the |I| spreads left by (17), so V_1 surfaces as |A.I|, with a [ɜ] realisation. There is also unshown A-licensing from C_1, so the |A| in /n̩/ is not actually required; but in words such as ‹|àń̩› ‘white bauhinia shrub’, it is.

Moraic /m̩/ also induces partial raising according to (11). However, Lionnet (2018) observes that in such words as ‹ǂ|ám̩› ‘sour taste’, Traill (1994) does not notate raising. The first author’s inspection of data from TDP shows no sign of raising in ‹C^{+}am› words. We predict partial raising, as the vowel remains empty; the simplest modification to block this would be to posit that moraic ‹m̩›, unusually, also contains |A|, for similar reasons as ‹n̩›. (Lionnet tentatively suggests that moraic nasals raise by some other mechanism.)

5.4. Pharyngealised V_1

Traill’s rule in (11) says that A-raising does not apply to pharyngealised V_1 at all, and we have not so far addressed this. There is a natural rule that a manner |A| (if that is how we represent pharyngealisation) licenses |A| in the place node, which blocks full raising, and indeed strengthens it by spreading to |A|, which reduces further any raising from I-spreading – doubly linked elements tend to show special strength in phonology (Honeybone 2005).

There is very limited audio data from Traill. However, in the data from TDP, it does appear that /$C_1^{\dagger}A^{\varsigma}C_2$i/ words display some raising, to near [æ].

We therefore suggest that there is no need to block partial raising for ‹$V_1{}^{\varsigma}$›, and that the reduced raising can be left to phonetic implementation.

6. Remaining issues

6.1. Apparent exceptions

6.1.1. Initial labials

The oral labials /p p^h p’ b f/ are marginal, occurring in C_1 position almost only in loanwords (whereas /b/ is a common C_2 sound). They are not mentioned as ‘front’ consonants in rule (11), and so we did not mention them in rule (12).

Normal phonology need not apply to loanwords, but if it does, then (12) predicts /pai/ as [pɜi], whereas our analysis, which explains partial raising in C_1V_1i words as active A-licensing from C_1, predicts [pii] – that is, in our analysis, labials are C^{+} consonants, not C^{-}.

Happily, Traill (1994) records words ‹péé-tî›, ‹píí› and even a native word ‹bi̱í› ‘[verb]’. There is no word recorded as ‹pai› – but there is the loanword ‹bái bìlì› ‘bible’. The latter also displays anomalous full raising, also found in the loanword ‹pilì sìì› ‘pill’.

It is thus at least as consistent with the data to say that labials are raising consonants as to say that they are not, and probably more so.

6.1.2. Initial velars

The initial velar consonants /k g k^h …/ would normally be considered ‘back’. However, our analysis in ET uses |A| as the active element, which corresponds more to lowness than to backness, and velars are arguably not low (and also not high). Indeed, the involvement of velars in the BVC varies across Khoisan languages. In the case of Eastern !Xóõ, rule (12) says they are C^{-} sounds, and thus we claimed they contain |A|.

However, while words ‹kái› and ‹kq̨́i› are noted in Traill (1994), there is also a relative pronoun ‹kVV› (and a monomoraic particle ‹kV›) which takes any of the forms ‹kaã kee kii kuu kn̩› depending on concord. Traill (1985) notes that the ‹ki› form is often replaced by ‹ti›. He suggests that the ambivalence of velars in the BVC is because they are the only ‘back’ consonants without pharyngeal narrowing.

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In the Western dialect in TDP, the same ambivalence applies: ‹kACi› words do not show [ɜ] (though they do sometimes sound [æ]-like, as described in (11c), which might be a weak raising), but words in ‹kii ke ki› exist.

It might be better to treat pulmonic velars as C^{+} consonants with just |U|, and deal with the missing raising as exceptions, than (as above) to treat them as C^{-} with exceptional raising.

6.2. /A/ with back rounded V2

So far, we have addressed only the realisation of V_1 = /A/ when it is followed by unrounded central/front /a e i/. What happens when it is followed by back rounded /o u/?

The element assignments and rules (16) and (17) give that after C^{+}, /A/ is [ɜ] before /u/ and [a] before /o/, while after C^{-} it is [a] in both cases.

Traill's (1994) description says nothing about ‹-ao-›, but does say that ‹a› is raised and rounded to mid central rounded [ɵ] before ‹u› – and gives an example with a back click, ‹ᵑ!au› 'salt pan' → [ᵑ!ɵu]. In Traill's published recordings, there are only two examples of such words: ‹ǂqᵡ'àů›, which appears to be spoken with [a], as we predict; and ‹ǂq'àù› 'lie horizontally [inflected]', which indeed appears with something like [ɵ], though the rounding is light.

In TDP, ‹-au-› words appear with a range of realisations. ‹ᵑ!áú› 'salt pan' is perhaps [ɜ – ɵ], and ‹ᵍ!áú› is perhaps similar (the words are too quickly spoken to be well analysed by spectrogram). The most strikingly affected word is (unsurprisingly) ‹táú›, which appears as [tɵʉ] or even fronter. On the other hand, ‹|háú› has roughly [æ] with little rounding, while ‹ǁʔáù› starts [ə – ɵ].

TDP has two examples of ‹$C^{+}_{|}$aCu› words, namely ‹ᵑ|ábú› and ‹ᵑ̊|ánú›. The centralisation of ‹a› is slight, a little more in the latter.

Thus, our rules predict raising more or less in accord with the data. However, there is also some spreading back of |U| in CVV words. This could be modelled in phonology by positing that |U| (unheaded) is realised as a rounded schwa (as Backley 2011 does for the reduced /ʊ/ of more conservative English RP); or it could be left to phonetics.

7. O-raising

So far, we have talked about A-raising, but our analysis has rules that apply equally well to /O/, so what of O-raising?

Previous work on A-raising has paid little or no attention to the case V_1 = /O/ (in the underspecified analysis). The little published information on assimilation of rounded V_1 is again from Traill (1985, 1994). It is interesting that Traill treats it completely separately from A-raising, and indeed describes it as /u/-lowering. Recall that he does not have the underspecified vowel idea, and so for him /o u/ are potentially contrastive in V_1.

Traill (1994: 41) describes rounded V_1 thus:

> **u > o/__ {a, e}** The high back vowel is lowered to a mid close back vowel when followed by **a** [*sic*]; the effect of this rule is to neutralise the contrast between the vowels **u, o**. For example, |**ua** is pronounced [|oa] and **!gue** [‹ᵍ!ue› in our notation] is pronounced as [!goe]. The lowering of **u** is somewhat more general than this rule suggests, but it appears to be restricted to a few arbitrary cases.

This suggests that /u/ and /o/ do exist contrastively in V_1 before V_2 = /i/, which would be incompatible with the underspecified analysis. In Traill (1994), there are 36 lexemes with ‹ui›, and only 2 with ‹oi› (‹ǁχòi̯› '[name of salt pan]' and ‹ǂχòi̯› 'bad, ugly'. These both have the uvular fricative accompaniment, and the lowering may be phonetic, given the widespread tendency of uvulars to lower vowels. There are lexemes entered as, for example, ‹ᵑǂχùí› 'hunting dog', so perhaps Traill was recording variation. In the revised dictionary (Traill 2018), the entry ‹ǁχòi̯› is still included by the editors, but so is a new

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entry ‹ǂχùĩ› '[name of a pan]' – it seems more likely that ‹ǂχùĩ› was intended to correct ‹ǂχòĩ› than that a contrast ‹oi/ui› is uniquely demonstrated in the names of salt pans.

Turning to words of the form ‹-{u,o}C_2i›, we find both recorded, with about three times as many ‹-u-› words as ‹-o-›. Some words are recorded with both forms (sometimes different tones: ‹ǀχólì› and ‹ǀχùlì› 'kneecap', ‹ᵑǃólí› and ‹ᵑǃùlì› 'spoil'. Many, but not all, of the ‹-o-› words have uvular C_1 or pharyngealised V_1. There are no minimal pairs. The data seem consistent with the claim that there is no ‹o/u› contrast, and what Traill recorded may have been free phonetic variation.

Even though Traill's rule says that the ‹u/o› contrast is neutralised before ‹-a›, he does record lexemes under both ‹-ua› and ‹-oa›. A striking entry is ‹ǃχóá› 'find', where the concordial form ‹ǃχóì› is noted as being pronounced [ǃχúi], raising ‹o›!

Finally, there are four entries notated ‹-ou›, along with many ‹-uu› words. These ‹-ou› are all in uvular context, and one (‹ǃχóù›) is a variant of the corresponding ‹-uu› form. They might be phonetic lowering, or, as a reviewer suggests, they could be misanalysed ‹-au› [-ɐu] forms.

We conclude that indeed there is no contrast between ‹u› and ‹o› in V_1 position, consistent with the underspecified vowel hypothesis. A possible objection is that Christfried Naumann writes in TDP (quoted with permission):

> There is a morphophonological tendency to vowel height assimilation, such as ‹ǀub-i› 'know-ɪ' *vs.* ‹ǀom-a› 'ostriches'. Contrasting pairs, however, exist, such as in ‹ǀoa› 'yesterday' *vs.* ‹ǀu-a› 'take-2SG' or ‹xoa› 'to write' *vs.* ‹xu-a› 'scratch-2SG'.

However, Naumann (p.c.) informs us that this is a preliminary and uncertain observation. Even if supported by other data, it could be a quasi-phonemic difference (Scobbie & Stuart-Smith 2008) rather than a true contrast, owing to the assimilation being reduced in dimorphemic words.

Does our analysis predict the correct behaviour? If rounding (the presence of |U|) is orthogonal to other features/elements, so that the /O/ is |U.A|, then A-licensing in (16) correctly predicts the value of [u] before /i/ and [o] before /a e/.[13]

It also predicts /o/ after lowering initials (C^{-}, $C^{ɢ}$). As we have seen above, Traill's transcription varies, and he writes ‹o› more often in lowering contexts. This is borne out by the audio data of TDP, where words notated with ‹-u(C_2)i› have a mid [o] or even [ɔ] in lowering contexts.

A complexity arises with the element |I|. The I-spreading rule in (17) predicts that in ‹-Oi›, the /O/ should become |U.I| – what is this? ET always struggles a little with large vowel spaces, and back unrounded vowels are rarely mentioned. However, in our ET, with a standard small set of elements plus heading, it is natural to posit that |I.U| is [y] and |U.I| is [ɯ]. This predicts that /ui/ should be pronounced more like [ɯi]. This is not mentioned by Traill. However, the couple of examples in TDP of ‹-ui› words (e.g., ‹dχùí› 'intestine', ‹ᵸʰùí-ᵸʰùí› 'be blue/pale', ‹ɬhùí-ɬhúí› 'be yellow') are partly unrounded; and the first author has observed, in work in progress, clear unrounding of /ui/ in recently published audio files of West !Xóõ. We thus claim a successful prediction of our rules.

8. Discussion

The phenomena of !Xóõ A-raising and similar processes in other Khoisan languages have attracted various descriptions. Traill (1985) describes the process informally, but though he develops a feature theory of !Xóõ, and extends it to a feature-geometric account in Traill (1993), he never presented a more formal description than (11). Nakagawa (2010), as mentioned, posits /A O/ specified only for rounding (and pharyngealisation), and states, without further analysis, that the remaining features are determined by the surrounding segments (according to the empirical description in Nakagawa

[13] A simple feature/element spreading account would predict different vowels [o ɒ] before /e a/, which is not found, whereas the combination of A-licensing and headed I-spreading works.

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2006). Miller-Ockhuizen (2003) argues for Jul'hoansi that front vowels can be underlyingly present after (what we have called) C^+ clicks, back vowels elsewhere, and that C^- clicks are [pharyngeal], triggering a constraint against adjacent front [coronal] vowels – that is, a phonotactic constraint rather than an assimilation. Miller (2010) phrases it informally as assimilation of front vowels to adjacent [RTR].

The most formally developed account is that of Bradfield (2014). He introduces an extension of an SPE-style theory with concurrent composition of segments, treating the pure click and accompaniment as phonemes in their own right. As with the use of multiple place nodes, this effectively allows features to occur twice in complex clicks, and his formal rule encapsulates (12) in terms of [±high] in click, accompaniment, and vowel. This is a gang effect, but makes no claims of gradience. Then Lionnet (2018), as we have discussed, argues that Bradfield's account is too simple and misses problems with the data, and Lionnet posits a more gradient approach, but without a formalisation. (As noted earlier, Traill 2018 removes most of the problems he noted.) He also considers it 'too complicated' to include /n̪/ in his analysis, and suggests an independent raising mechanism, whereas we include it without complication.

These analyses all rely on somewhat idiosyncratic variations of processes such as assimilation. In our analysis, however, various independent, and elsewhere attested, phonological assimilations join to generate the pattern of gradient raising in !Xóõ. There is an umlaut-like operation of featural spreading of |I|, and there is a metaphony-like operation of featural licensing of |A|. The apparent gradience comes from the different phonological environments that trigger one or both of these operations.

This puts !Xóõ in a typological class of languages that regulate the presence of 'lowness', or the element |A|, in their grammar. Such conditions are language-specific, in their rules and specific phonetic interpretations, but are still under the umbrella of |A|-licensing. This account of metaphony allows a connection to an opposite effect, the process of low-vowel dissimilation, as seen in some Oceanic languages such as Alamblak (Bruce 1984; Blevins 2009; Blevins & Pawley 2010). In Alamblak, consecutive [a] vowels are banned, and depending on their position one of a sequence of /a/s 'raises' to [ə]. In our account, this is effectively the opposite of metaphony, but it can use the same mechanism: 'lowness' cannot be licensed by another 'low'. So, instead of forming an association line between the V-slot and |A| under |A|-licensing, here we remove it, as in (25a) and (25b). As we see in (25c), /a/ is allowed to surface only if it is not licensed by /a/ (Blevins 2009: 479).[14]

(25) *Alamblak dissimilation*

a.	/w**a**-w**a**j-n-**a**/ IMP-give-2SG-1SG	[w**a**ɣəjn**a**]	'give to me'
b.	/w**a**ɲ-t**a**ɲ-x**a**tə/ hear-COMPL-SA	[w**a**ɲtəɲx**a**tə]	'having heard'
c.	/xiŋgn**a**-ni-r**a**xr/ work-go-FUT.3SG.M	[xiŋgɨn**a**nir**a**ɣɨr]	'he will work (and go)'

Connecting metaphony to this dissimilatory process via the reversal of the same mechanism is impossible for the traditional account of metaphony as vowel harmony that spreads [+high] (e.g., Walker 2005).

In a further similarity with the !Xóõ data, in some varieties of Southern Russian there is a high, and not-so-high, vowel raising caused by low-vowel dissimilation (Blevins 2009). As with other Slavic languages, mid vowels undergo simplification. For instance, /o/ becomes [a] in unstressed position, as in (26a), while if the ensuing vowel is /a/ the stem's /o/ 'raises' to schwa, as in (26b). If, however, the /o/ follows a palatalised consonant, it raises all the way to [i], as in (26c).

[14] [ɨ] is non-lexical.

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(26) *Southern Russian vowel raising* (Nesset 2002, quoted in Blevins 2009: 481)

a. /nʲoˈsti/ 'to carry' → [nʲaˈsu] 'carry.ISG.PRES', [nʲaˈsʲi] 'carry.2SG.IMP'

b. /soˈva/ → [səˈva] 'owl.NOM.SG'
(cf. [saˈvu] 'owl.ACC.SG', [saˈvɨ] 'owl.GEN.SG')

c. /nʲoˈsla/ → [nʲiˈsla] 'carry.F.SG.PRET'
/pʲatʲ/ 'five' → [pʲiˈtak] 'fiver'

This could be taken as a simple gradient vowel dissimilation and raising. However, in our account, it is just the non-licensing of /a/ by another /a/, like the Alamblak – the opposite of metaphony – in combination with the harmonic spreading of |I| from C to V.

Our definition of metaphony as a form of low licensing, acting potentially in concert with assimilations, opens the door to research into all of the possible iterations of low licensing that can exist across languages.

9. Conclusion

We have examined the process of metaphony and cast it in an Element-Theoretic framework, whereby metaphony is clearly distinguished from the apparently similar phenomenon of umlaut that it indeed originally translated (§2.3). We have then applied this analysis to what has previously appeared to be an extremely complex assimilation phenomenon in a language already famed for its phonological complexity. Bradfield (2014) argued that much of the phonological complexity was overstated, saying that rather !Xóõ simply makes more extensive use of a 'concurrent' segment composition technique than other languages. Here, by analysing !Xóõ in the framework of ET, we have shown that the complex assimilation is a combination of two phenomena well known from even European languages, namely umlaut and metaphony.

These assimilatory and licensing phenomena are also made more complex by a larger set of conditions on what triggers licensing and blocks spreading. There is a further complication in the way that !Xóõ allows nasals to sit in vowel slots. Our analysis handles all these factors. Moreover, the analysis provides for free a good description of the usually overlooked O-raising aspect of !Xóõ vowel harmony (as other analyses could too with a little tweaking), and predicts a novel aspect, O-unrounding, that is indeed found.

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