Phonological Teamwork in Kalahari Basin Languages

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Abstract

This paper describes the complex, multiple-trigger, cumulative assimilation processes targeting the initial vowel (V_1) of bimoraic stems in Kalahari Basin languages, first described by Anthony Traill (1985) in East !Xoon (Tuu). The focus is on two languages: East !Xoon and G|ui (Khoe-Kwadi). The goal is to describe these processes in as much detail as is possible from the available published and unpublished sources. Marked differences between the two languages in focus are brought to light, thus giving an idea of the so far unnoticed diversity of V_1 realization in KBA languages. Finally, this paper briefly highlights important problems posed by such cumulative processes to phonological theory, many of which had already been identified by Traill (1985).

Keywords: gradience, multiple trigger, cumulative assimilation

1. Introduction

This paper describes a complex kind of cumulative coarticulatory/assimilatory effect involving multiple triggers and targeting the first vowel of bimoraic lexical roots in many Kalahari Basin Area (henceforth KBA) languages. The focus is on two linguistic varieties: the East !Xoon dialect of Taa (Tuu family) and G|ui (Khoe Kwadi).

Lexical roots in most KBA languages are subject to very strict phonotactic restrictions on both shape and internal phoneme distribution (Beach 1938; Traill 1985; Miller-Ockhuizen 2001; Miller 2010; Nakagawa 2006; Nakagawa 2010; Naumann forthcoming; see Güldemann and Nakagawa, this volume, pp. XX-XX for an overview and up-to-date summary). As shown in (1) below, lexical roots are always bimoraic, and may be of three shapes only.[1]

(1) OV_1.$C_m V_2$ (O = onset, either C, or cluster C_1C_2; C_m = medial consonant)
OV_1V_2 (likely from OV_1.~~C_m~~V_2)
OV_1N (probably from OV_1.N~~V_2~~)

Building on research by Beach (1938) and Traill (1985), Nakagawa (2010) analyzes the distribution of consonants and vowels within KBA lexical roots as shown in Figure 1. The root-initial consonant(s) (O) is the locus of maximal lexical distinction, most of the consonants, including all clusters, being attested in this position. The medial consonant C_m and final N are, on the other hand reduced to sonorants (and /b/ = [b~β]) and nasals respectively. As for vowels, V_1 is underlyingly specified only for guttural features (i.e. phonation type) and non-dorsal features (i.e. rounding). Only V_2 is specified for dorsal features (height and backness) and nasality. This analysis, based on G|ui data, holds for most KBA languages (cf. Güldemann and Nakagawa, this volume, p. XX).[2]

O	V_1	C_m	V_2
|	|	|	|
Obstruents	**Non-dorsal**	**Sonorants**	**Dorsal**
incl. clusters	[±round]	(Obstruents)	[±high, ±low]
(Sonorants)	[guttural]		[±back]
			[±nasal]

Figure 1: Distribution of C and V features in KBA lexical roots (after Nakagawa 2010)

[1] The term "root" follows the terminological tradition set by Beach's (1938) phonetic study of Khoekhoe.

[2] The following phonation types are attested in KBA languages (not all languages have all of them): pharyngealized /Aˤ, Uˤ/, glottalized /Aˀ, Uˀ/, breathy /A̤, Ṳ/, strident /A̤ˤ, Ṳˤ/, pharyngealized and glottalized /Aˤˀ, Uˤˀ/, glottalized and breathy /A̤ˀ, Ṳˀ/. Nasality usually spreads leftward from V_2 (or N) to V_1, while pharyngealization has a tendency to spread rightward from V_1 to V_2 in C(C)$V^{ˤ}_1V_2$ roots (cf. Güldemann and Nakagawa, this volume, p.XX).

Taking only vowel quality into account, V_1 is thus underlyingly either [–round] /A/ or [+round] /U/. On the surface, however, V_1 displays a wide range of possible realizations: /U/ may be realized as [u], [ʉ], [ʊ], or [o], while /A/ covers a larger range, from peripheral [a, e, i] to central [ɨ, ə, ɜ, ɐ]. These realizations are entirely determined by complex coarticulatory and assimilatory processes involving some or all of the neighboring consonants and vowels (V_2, O, C_m, N).[3]

The object of the present paper is precisely to characterize these coarticulatory/assimilatory effects in two languages: East !Xoon (Tuu) and G|ui (Khoe-Kwadi). These effects are interesting for at least two reasons. First, they constitute a particularly complex and rich case of "subphonemic teamwork" (Lionnet 2016, 2017): they indeed often involve scalar effects with more than one trigger, as well as complex trade-off relations between competing triggers. Second, these teamwork effects seem to blur the distinction between (gradient) phonetics and (categorical) phonology, and to question aspects of contemporary phonological theory. For the sake of both simplicity and saving space, this paper focuses exclusively on /A/, but similar generalizations hold for /U/.

Section 2 describes the principles governing the realization of V_1 /A/ in East !Xoon. Section 3 describes the phonetic underpinnings of the East !Xoon patterns, as analyzed by Traill (1985). Section 4 looks at the effect of the intervening second consonant in complex onsets, specifically at the transparency of all but the uvular fricative [χ] and affricate [q͡χ']. Section 5 describes the realization of V_1 /A/ in G|ui, and shows that despite striking similarities with East !Xoon, they are substantially different. Section 6 briefly highlights the relevance of these patterns for phonological theory, and section 7 concludes.

2. The case of East !Xoon

Reliable phonetic and phonological descriptions are available for two dialects of Taa: East !Xoon (or !Xóõ; Traill 1985) and West !Xoon (Naumann forthcoming). In this section, I use Traill's East !Xoon data (mostly because Traill presents richer acoustic and articulatory data), adopting the phonological (re-)analysis developed by Naumann (forthcoming) for West !Xoon, in particular with regard to the consonant system. Naumann identifies more consonantal contrasts than Traill did, and, based on preliminary comparative data, says that most of these contrasts are probably also present in the eastern dialect.[4] The consonant inventory of Taa is presented in Table 1 below, where the shaded cells indicate the consonants that take part in the multiple-trigger raising and fronting assimilation described in this section.

[3] Throughout this paper, the IPA symbol [a] stands for the low back vowel [ɑ].
[4] Bradfield (2014) similarly adopts Naumann's inventory while using Traill's East !Xoon data.

<table>
<tr><td></td><td colspan="3">Egressive</td><td colspan="5">Ingressive</td><td colspan="4">Egressive</td></tr>
<tr><td></td><td>labial</td><td>alveolar</td><td>alv. affr. /palatal</td><td>labial</td><td>dental</td><td>alveolar</td><td>palatal</td><td>lateral</td><td>velar</td><td>uvular</td><td>uvular-</td><td>glottal</td></tr>
<tr><td colspan="13">Oral stops</td></tr>
<tr><td>Plain</td><td>p</td><td>t</td><td>t͡s</td><td>⊙</td><td>|</td><td>!</td><td>ǂ</td><td>‖</td><td>k</td><td>q</td><td></td><td>(ʔ)</td></tr>
<tr><td>Voiced</td><td>b</td><td>d</td><td>d͡z</td><td>⊙̬</td><td>|̬</td><td>!̬</td><td>ǂ̬</td><td>‖̬</td><td>g</td><td>ɢ</td><td></td><td></td></tr>
<tr><td>Vl. aspirated</td><td>p^h</td><td>t^h</td><td>t͡s^h</td><td>⊙^{h}</td><td>|^h</td><td>!^{h}</td><td>ǂ^h</td><td>‖^h</td><td>k^h</td><td>q^h</td><td></td><td></td></tr>
<tr><td>Vd. aspirated</td><td>b^h</td><td>d^h</td><td>d͡z^h</td><td>⊙̬^{h}</td><td>|̬^{h}</td><td>!̬^{h}</td><td>ǂ̬^{h}</td><td>‖̬^{h}</td><td>g^h</td><td>ɢ^h</td><td></td><td></td></tr>
<tr><td>Vl. ejective</td><td>p’</td><td>t’</td><td>t͡s’</td><td>⊙’</td><td>|’</td><td>!’</td><td>ǂ’</td><td>‖’</td><td>k’</td><td>q’</td><td>q͡χ’</td><td></td></tr>
<tr><td>Vd. ejective</td><td></td><td></td><td>d͡z’</td><td></td><td>|̬’</td><td>!̬’</td><td>ǂ̬’</td><td>‖̬’</td><td>g’</td><td>ɢ’</td><td>ɢ͡ʁ’</td><td></td></tr>
<tr><td colspan="13">Nasal stops</td></tr>
<tr><td>Plain (vd.)</td><td>m</td><td>n</td><td>ɲ</td><td>⊙̃</td><td>|̃</td><td>!̃</td><td>ǂ̃</td><td>‖̃</td><td>ŋ</td><td></td><td></td><td></td></tr>
<tr><td>Voiceless</td><td></td><td></td><td></td><td></td><td>|̥̃</td><td>!̥̃</td><td>ǂ̥̃</td><td>‖̥̃</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Glottalized</td><td>^{ʔ}m</td><td>^{ʔ}n</td><td></td><td>^{ʔ}|̃</td><td>^{ʔ}!̃</td><td>^{ʔ}ǂ̃</td><td>^{ʔ}‖̃</td><td>^{ʔ}|̃</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Fricatives</td><td>f</td><td>s</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>χ</td><td></td><td>h</td></tr>
<tr><td>Sonorants</td><td>w</td><td>l, r</td><td>y</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="13">Obstruent clusters</td></tr>
<tr><td>Plain+ q</td><td></td><td></td><td></td><td>⊙q</td><td>|q</td><td>!q</td><td>ǂq</td><td>‖q</td><td></td><td></td><td></td><td></td></tr>
<tr><td>+voice</td><td></td><td></td><td></td><td>⊙̬q</td><td>|̬q</td><td>!̬q</td><td>ǂ̬q</td><td>‖̬q</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Plain+ q^h</td><td></td><td></td><td></td><td>⊙q^h</td><td>|q^h</td><td>!q^h</td><td>ǂq^h</td><td>‖q^h</td><td></td><td></td><td></td><td></td></tr>
<tr><td>+voice</td><td></td><td></td><td></td><td></td><td>|̬q^h</td><td>!̬q^h</td><td>ǂ̬q^h</td><td>‖̬q^h</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Plain+ q’</td><td></td><td></td><td></td><td>⊙q’</td><td>|q’</td><td>!q’</td><td>ǂq’</td><td>‖q’</td><td></td><td></td><td></td><td></td></tr>
<tr><td>+voice</td><td></td><td></td><td></td><td></td><td>|̬q’</td><td>!̬q’</td><td>ǂ̬q’</td><td>‖̬q’</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Plain+ χ</td><td></td><td>t͡χ</td><td>ts͡χ</td><td>⊙χ</td><td>|χ</td><td>!χ</td><td>ǂχ</td><td>‖χ</td><td></td><td></td><td></td><td></td></tr>
<tr><td>+voice</td><td></td><td>d͡χ</td><td>dz͡χ</td><td>⊙̬χ</td><td>|̬χ</td><td>!̬χ</td><td>ǂ̬χ</td><td>‖̬χ</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Plain+ q͡χ’</td><td>pq͡χ’</td><td>tq͡χ’</td><td>t͡sq͡χ’</td><td>⊙q͡χ’</td><td>|q͡χ’</td><td>!q͡χ’</td><td>ǂq͡χ’</td><td>‖q͡χ’</td><td></td><td></td><td></td><td></td></tr>
<tr><td>+voice</td><td></td><td>d͡zq͡χ’</td><td>d͡zq͡χ’</td><td>⊙̬q͡χ’</td><td>|̬q͡χ’</td><td>!̬q͡χ’</td><td>ǂ̬q͡χ’</td><td>‖̬q͡χ’</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Plain+ ʔ</td><td></td><td></td><td></td><td>⊙ʔ</td><td>|ʔ</td><td>!ʔ</td><td>ǂʔ</td><td>‖ʔ</td><td></td><td></td><td></td><td></td></tr>
<tr><td>+voice</td><td></td><td></td><td></td><td>⊙̬ʔ</td><td>|̬ʔ</td><td>!̬ʔ</td><td>ǂ̬ʔ</td><td>‖̬ʔ</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Plain+ h</td><td></td><td></td><td></td><td>⊙h</td><td>|h</td><td>!h</td><td>ǂh</td><td>‖h</td><td></td><td></td><td></td><td></td></tr>
<tr><td>+voice</td><td></td><td></td><td></td><td>⊙̬h</td><td>|̬h</td><td>!̬h</td><td>ǂ̬h</td><td>‖̬h</td><td></td><td></td><td></td><td></td></tr>
</table>

Table 1: Consonants of West !Xoon (Taa), including clusters (after Naumann, forthcoming.)

Traill (198: 69-70) notes that V_1 /a/ (/A/ in the notation adopted here) is subject to coarticulatory and assimilatory raising and fronting effects from neighboring segments:

> The vowel **a** has the greatest number of contextual variants and is subject to assimilatory pressure from both a preceding consonant and succeeding consonant or vowel. It is raised and fronted when followed by **i**, **e** either

> contiguously, or after an intervening consonant. The greatest assimilatory effect on **a** is exerted by the combined effects of a preceding dental consonant such as **t**, **l**, **ǂ** and a following **i, n**. In this environment, **a** is pronounced either as a lowered-high and slightly centralized vowel [ɪ], or as a raised-mid central [ɜ]. In certain cases, it may assimilate fully to the high tongue position of the surrounding consonants and [i] yielding a long [iː].

The assimilation patterns described by Traill involve several potential triggers, sometimes operating together: /A/ partially or fully assimilates to a following front vowel /i e/ if it is preceded by a subset of coronal consonants, which includes all coronal egressive consonants, and all the dental /ǀ ǀ̃ ǀʰ…/ and palatal /ǂ ǂ̃ ǂʰ…/ clicks. This set of coronal consonants is shaded in Table 1, and detailed in Table 2 below. I will henceforth represent it as $C_{[+]}$ (vs. $C_{[-]}$ for the consonants that do not participate in the assimilatory patterns; the coronal consonants included in $C_{[-]}$ are shown in Table 2).[5]

Included coronals (= $C_{[+]}$)	Egressive:	t, d, tʰ, dʰ, t’, s, ts, d͡z, t͡sʰ, d͡zʰ, t͡s’, d͡z’
	Clicks	ǀ and ǂ series
Excluded coronals (⊂ $C_{[-]}$)	Clicks:	! and ǁ series

Table 2: $C_{[+]}$ and $C_{[-]}$ coronals in in East !Xoon

The target vowel may be modal /A/, glottalized /Aˀ/, or breathy /A̤/, but not pharyngealized /Aˤ, Aˤˀ/ or strident /A̤ˤ/, which are not affected. This is expected, as pharyngealization is articulatorily antagonistic to raising (cf. section 3). The effects mentioned by Traill are illustrated in (2)-(4) below with words taken from his dictionary (Traill 1994; see also Traill 1985: 91).[6]

(2) /A/ → [i] / $C_{[+]}$__i

/tÀ̤i/	[ti̤i]	‘pad (of paw)’	cf. pl. **ta̤ba-tê**
/sÂ-i/	[síi]	‘come to-CLASS.1ii’	cf. **sá-ã** ‘come to-CLASS.2ii’
/ǀ̃Â-i/	[ǀ̃íi]	‘see-CLASS.1’	cf. deverbal form **ǀ̃âã**
/ǂÀi/	[ǂìi]	‘steenbok’	cf. pl. **ǂàba-tê**

(3) /A/ → [e] / $C_{[+]}$__e

/tÀ̤’-e/	[tè̤’e]	‘welcome-CLASS.3’	cf. deverbal form **tà̤’a**
/ǀ̃Ā-e/	[ǀ̃ēe]	‘see-CLASS.3i’	cf. deverbal form **ǀ̃âã**
/ǂÂẽ/	[ǂêẽ]	‘jaw’	cf. pl. **ǂâm(a)-tê**

[5] The only two coronal egressive consonants that are not in this list are **n** and **ˀn**. There are very few lexical stems in the dictionary that start with either of these consonants (**n** = 25, **ˀn** = 4), and none of them presents the phonotactic characteristics conducive to the raising and fronting assimilation. This is very likely to be an accidental gap.

[6] Traill does not provide a phonetic transcription for each entry in the dictionary, but only for a few (most of the time to indicate raising and fronting). Many entries where the conditions for raising and fronting are met do not include such a transcription. It is unclear whether these are exceptions or if this is just due to inconsistency on the part of the author. I tentatively assume the latter.

(4) /A/ → [ɜ]~[ɪ] / $C_{[+]}$__C_{m}i
 a. C_{m} = non-coronal **b, m**
  /ʔÁi dʰÁbi/ [ʔíi dʰɜ́bi] male name
  /sÀmi/ [sɜ̀mi] ‘spin’
  /ǂÁbi/ [ǂɜ́bi] ‘young steenbok’
 b. C_{m} = coronal **n, l**
  /tʰĀli/ [tʰɜ̄li] ‘skin for carrying a child’
  /sÁni/ [sɜ́ni] ~ [síni] ‘pre-orbital gland, scent mark’
  /ǂÀl-i/ [ǂɪ̀li] ‘fold-CLASS.1ii’

The examples (2)-(4) above illustrate two types of changes: total assimilation of /A/ to V_2 (raising and fronting of /A/ to [i] or [e]), and partial assimilation (raising of /A/ to [ɜ ~ ɪ]). Both are allophonic.

As shown in (5), total assimilation of /A/ to [i] or [e] is also observed when the initial consonant is a glottal stop /ʔ/, which lacks a place feature, and is thus articulatorily neutral, i.e. neither $C_{[+]}$ nor $C_{[-]}$.

(5) /A/ → {[i], [e]} / ʔ_{i, e}
 /ʔÁi dʰÁbí/ [ʔíi dʰɜ́bí] male name
 /ʔÂ-i/ [ʔìi] ‘eat-CLASS.ii’ cf. deverbal form **ʔâã**
 /ʔÂ-e/ [ʔēe] ‘eat-CLASS.3i’

These examples constitute evidence for the intrinsic full assimilatory effect of a front V_2 on an immediately preceding /A/, in the absence of any effect from the other neighboring segments.

With any other initial consonant, i.e. $C_{[-]}$, only partial assimilation is attested: /A/ is raised to [ɜ], and sometimes fronted to [æ ~ ɛ ~ e], as shown in (6) and (7) below, with the few examples I could find in Traill’s (1994) dictionary, where indication of this partial assimilation is unfortunately only rarely provided.[7]

(6) /A/ → [ɜ~æ~i] / $C_{1[-]}(C_2)$_i
 /!Âĩ/ [!êĩ] ‘non-burning end of a stick’
 /ǁAi/ [ǁæi] ?[8]

(7) /A/ → [ɜ~æ~ɛ] / $C_{1[-]}(C_2)$_e
 /!̃Áe/ [!̃ǽe] ‘die down (of the wind)’

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[7] Bradfield (2014: 36) notes that in Traill’s East !Xoon (!Xóõ) recordings on the UCLA phonetics lab archive “all <-ai> words with back clicks appear to show the same degree of raising as other cases of moderate raising. There is not enough data to make any statistically meaningful claim, but both auditory impression and acoustic measurements suggest this. For example, in one recording <!hai> appears to show considerable assimilation, varying from [əi] to [ɛi] in the same speaker.”

[8] This example is given by Traill (1994: 40) without a translation. It is probably one of the following three words, for which no phonetic transcription is provided in the dictionary: **ǁāi** ‘hole dug by sexually mature wildebeest and hartebeest to mark territory’, **ǁài** ‘persistent rains’, or **ǁài** ‘move close together’.

/ǁÂe/	[ǁɛ̂ɛ]	‘three’
/|̃Áɲa ǁʔÁe/	[|̃ɜ́ɲa ǁʔǽe]	personal name

The $C_{[-]}$ consonants in (6) and (7) are not neutral (contrary to /ʔ/, cf. (5)), but seem to counteract the effect of the following front vowel, by preventing it from affecting the target vowel to the full extent of its power.

The nature of the intervening C_m in the $C_{[+]}$__C_mi context also seems to be relevant to the assimilation pattern (the only six C_m attested in East !Xoon are /b/ [b~β], /ɟ/ [ɟ~j], /m/, /n/, /ɲ/, and /l/). As can be seen in (4)a above, when C_m is non-coronal [b, m], the cumulative effect of $C_{[+]}$ and /i/ raises /A/ to [ɜ]. When C_m is a coronal [l, n], as in (4)b, raising to [ɪ] (/ǂÁl-i/ → [ǂɪ́li]) and even full assimilation to [i] (/sáni/ → [sɜ́ni] ~ [síni]) are attested, which indicates that the intervening coronal helps the assimilation by adding some of its assimilatory power. Finally, a palatal C_m (mostly /ɲ/, /ɟ/ being extremely rare in C_m position) seems to be strong enough as a trigger to have a raising and fronting effect on V_1 /A/ even when the following vowel is the low back vowel /a/, as shown in (8).

(8) /A/ → [ɜ~e~i] / $C_{[+]}$_ɲa[9]

/ˀ|̃Àɲa/	[ˀ|̃ɜ̀ɲa]	‘marriage’
/|̃Áɲa ǁʔÁe/	[|̃ɜ́ɲa ǁʔǽe]	personal name
/ǂ̬À̤ɲa/	[ǂ̬é̤ɲa]	‘dew claw of a lion’[10]
/ǂ̬Áɲa/	[ǂ̬éɲa]	‘pout’
/qÂi tʰÀɟa/	[tʰàɟa] ~ [tʰìɟa]	‘work metal, hammer flat’

The properties of the assimilation pattern described so far are summarized in Table 3, where the degree of assimilation is represented by different shades of gray (the non-low back vowels /o, u/ are omitted for the sake of simplicity). Note that it is not clear what effect the combination of $C_{[+]}$__ and __C_me (i.e. $C_{[+]}$__Je, $C_{[+]}$__Le, and $C_{[+]}$__Be) has on V_1 /A/: based on Traill’s description quoted above, one would expect /A/ → [ɜ] raising. One would also expect the raising and fronting effect of __C_me to be less important than that caused by __C_mi (e.g. [ɜ~ɛ~e] rather than [ɜ~ɪ~i]). However, I could not find any illustration of this in Traill’s (1985) description, nor in his dictionary, which could be an indication either that there is no effect, or that the effect is less salient. I will thus ignore the $C_{[+]}$__C_me contexts in the remainder of the discussion.

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9 There are three more $C_{[+]}$_ɲa words in the dictionary for which no phonetic transcription is given: **tà’ɲa** ‘thank’, **|āhɲa** ‘red’, and **ǂá’ɲa** ‘black’. Whether these are exceptions is unclear. Note also the /A/ → [i] full assimilation in /mÁ̰ɲa/ → [mḭ́ːa] (from [mḭ́ɲa]) ‘kin’, despite the initial $C_{[-]}$.

10 This and the next word are listed in the dictionary as **ǂgèhɲa** and **ǂgéɲa** respectively. I have taken the liberty to interpret V_1 as being underlyingly /A/, in accordance with the analysis adopted here.

	OV_1V_2			$OV_1C_mV_2$								
	_i	_e	_a	_Ji	_Je	_Ja	_Li	_Le	_La	_Bi	_Be	_Ba
ʔ_	i	e	a	–	–	–	–	–	–	–	–	a
$C_{[+]}$_	i	e	a	–	–	ɜ~i	ɜ~i	ɜ?	a	ɜ	ɜ?	a
$C_{[-]}$_	ɜ~e	ɜ~ɛ	a	–	a	a	a	a	a	a	a	a

Table 3: realization of V_1 = /A/ in all O__(Cm)V_2 contexts in East !Xoon ("–" = unattested combination)

Table 3 clearly illustrates the cumulative effect at work in this pattern, and the different levels of assimilatory strength of the co-triggers involved. The post-target front vowels _{i,e} are strong enough to fully assimilate an immediately preceding /A/, as revealed by their effect in isolation, that is, with neutral /ʔ/ in onset position (cf. (5) above). This makes them the strongest triggers. All the other co-triggers are weaker: they do not have any effect on their own. However, they can team up with other weak co-triggers to either raise /A/ to a non-low central vowel [ɜ~ɪ] or raise and front it to [i, e], depending on their relative strengths, as illustrated in the trigger strength hierarchy in Table 4 and Table 5.

High/front assimilatory strength						*Counteracting effect*		
super-strong		*strong*		*weak*		*weak*		*strong*
__i	>	__e	>	$C_{[+]}$__, __J	>	__L	<	$C_{[-]}$, __B

Table 4: Trigger strength in East !Xoon fronting/raising

	[+] *High/front assimilatory strength*		[–] *Counteracting effect strength*
super-strong	_i	↑	
strong	_e		$C_{[-]}$_, _B
weak	$C_{[+]}$_, _J		_L
neutral		ʔ	

Table 5: High/front assimilatory strength scale in East !Xoon

The strength of the effect of /i e/ on a preceding /A/ also depends on distance: it disappears when both vowels are separated by an intervening consonant, unless the consonant immediately preceding the target is of the $C_{[+]}$ type, in which case the conjoined effort of these two co-triggers still depends on the nature of the intervening consonant. Intervening palatals ($C_{[+]}$) are strong enough to qualify as one of the two co-triggers needed to raise /A/ to [ɜ] and sometimes even to fully assimilate it to [i]. Dentals ($\subset C_{[+]}$) are only strong enough to help two existing co-triggers to push the assimilation a little further than [ɜ]. Finally, labials ($\subset C_{[-]}$) seem to have a similar counteracting effect to that of initial $C_{[-]}$.

The effects of all the possible trigger combinations are summarized in Table 6, where the notation [a~b] stands for a continuum of attested phonetic realizations from [a] to [b], e.g. [ɜ~i] refers to any realization between [ɜ] and [i] on the low/back to high/front diagonal, including [ɪ], [ɛ], [e] (cf. Figure 2 below).

Trigger strength					*Triggers*	*Effect*	
ss[+]	s[+]	w[+]	w[–]	s[–]			
✓		(✓)			(C[+])_i	/A/ → [i]	strongest effect
	✓	(✓)			(C[+])_e	/A/ → [e]	
✓		✓	✓		C[+]_Li	/A/ → [ɜ~i]	
		✓✓			C[+]_J		
✓				✓	C[–]_i	/A/ → [ɜ~e]	
	✓			✓	C[–]_e	/A/ → [ɜ~ɛ]	
✓		✓		✓	C[+]_Bi	/A/ → [ɜ]	weakest effect
		✓			C[+]_		
		✓			_J		
✓			✓		_Li		
✓			✓	✓	C[–]_Li	/A/ = [a]	no effect
✓				✓	_Bi		
✓				✓✓	C[–]_Bi		
		✓		✓	C[–]_J		
				✓	C[–]_		

Table 6: trigger combinations and their effects in East !Xoon

I have until now ignored one of the triggering contexts mentioned by Traill (1985: 70, 1994: 40): $C_{[+]}$__N, where N represents a coda [m] or [n]. We saw earlier what effect the three nasals [m, n, ɲ] have when they occupy the C_m slot in a $C_{[+]}$__C_mV_2 word (cf. (8) and preceding prose). Traill (1994: 40) does not establish any difference between coda nasals and C_m nasals with respect to their role in high/front assimilation, and simply lists $C_{[+]}$__m, $C_{[+]}$__n, and $C_{[+]}$__ɲ as co-triggering contexts. However, coda nasals do not behave like C_m nasals. Coda [n] systematically causes /A/ to raise to [ɜ], whatever the nature of the preceding consonant(s), as illustrated in (9). Note that coda [m] does not seem to have any effect on a preceding /A/ (or at least, no <C(C)am> entry in the dictionary includes a phonetic transcription that would show a raising effect).

(9) /A/ → [ɜ] / __n

a. $C_{1[+]}(C_2)$_n

/tÁ-n/	[tɜ́n]	‘to-CLASS.5’
/sÂ-n/	[sɜ́n]	‘come to-CLASS.5i’
/t͡s’Án/	[t͡s’ɜ́n]	‘taste’
/ǀ̃Àn/	[ǀ̃ɜ̀n]	‘head’
/ˀǂ̃Ā̤n-tê/	[’ǂ̃ɜ̤̄n-tê]	‘sack (pl.)’

b. $C_{1[-]}(C_2)$_n

/k-Án/	[kɜ́n]	‘copula-CLASS.5’
/b-Ān/	[mɜ̄n]	‘because-1SG’ (NB: nasal harmony)
/ǁqʰÀ-n/	[ǁqʰɜ̀n]	‘different-CLASS.5

The examples in (10) below show that /n/ has this raising effect only when in coda position.[11]

(10) /ǂʔÀn/ [ǂʔɜ̀n] ‘penis (sg.)’
/ǂʔÀna/ [ǂʔàna] ‘penis (pl.)’

Given the lack of difference between $C_{[+]}$__n and $C_{[–]}$__n, I have decided to exclude coda nasals from the set of triggers, tentatively choosing to see the systematic raising effect it causes as an independent phenomenon. It would not be difficult to include it among the triggers, but would complicate the already complex description.

3. Phonetic underpinnings

As noted by Traill (1985: 114), these assimilation patterns involve both raising and fronting. This is clearly shown in the vowel plot in Figure 2, where the various realizations of /A/ form a diagonal from low/back [a] to high/front [i].

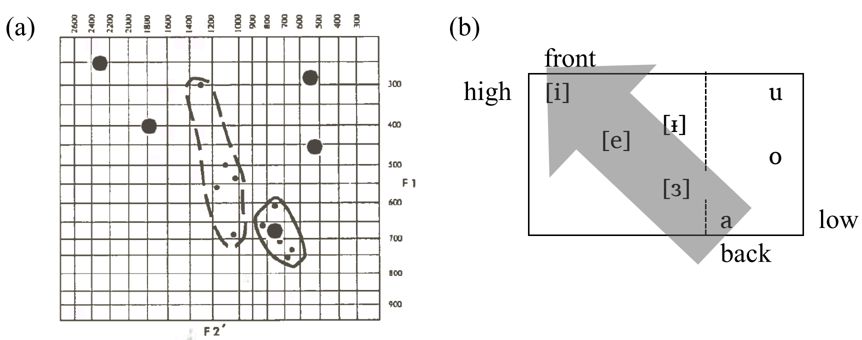

Figure 2: (a) F1 by F2' (i.e. F2–F1) plot of East !Xoon modal [i e a o u]. The large dots represent average values from V_1’V_2 and V_1V_2 sequences ($V_1 = V_2$). The scatter for non-coarticulated [a] (solid line) and raised [a] (broken line) is plotted with small dots. (adapted from Traill’s (1985:71-72) Figures 5 and 6). (b) a schematized version, the arrow highlighting the [a]-[i] diagonal along which the realizations of V_1 /A/ are distributed.

The role of the $C_{[+]}$ consonants “seems to be that they facilitate the raising process” (Traill 1985: 114). Traill shows that the crucial explanation of the different behavior of $C_{[+]}$ and $C_{[–]}$ consonants lies in their articulatory properties: $C_{[+]}$ consonants are laminal, $C_{[–]}$ are not. $C_{[+]}$ consonants thus involve extensive contact between the front part of the tongue and the region of the palate comprised between the upper teeth and the alveo-palatal region, and can only be articulated with a raised and fronted tongue body, which is directly responsible for the raising/fronting effect. This distinction explains why alveolar [!] does not belong to the $C_{[+]}$ category, despite being coronal like all $C_{[+]}$: it is indeed not laminal, but apical. In order to

[11] Alternatively, one could see the difference between [ǁʔɜ̀n] and [ǁʔàna] as resulting from the counteracting effect of the following low/back vowel, preventing raising.

maintain the apico-alveolar closure during the production of [!], the post-apical part of the lamina is lowered and kept away from the palate. The same can be said about the articulation of lateral [ǁ] (⊂ $C_{[-]}$), which also involves an apico-alveolar constriction. Traill (1985: 109) notes that "the two laminal clicks [ǀ] and [ǂ] have generally a greater amount of tongue contact with the palate than the apical clicks [!] and [ǁ]." This can be seen on the tracings in Figure 3.

The high and front position of the tongue involved in the articulation of laminal segments is what is important here, in particular after the anterior release. As shown in Figure 3 with the superimposed tongue outline for the hold positions of the five clicks and the vowels [i, e, a], the articulation of the laminal clicks [ǀ, ǂ] brings the middle and front parts of the tongue to a position that is very close to that required for the production of [i] and [e]. "Conversely, the apicality of [!] and [ǁ] and its magnification during suction introduces an articulatory distance from [i] and [e]" (Traill 1985: 116).

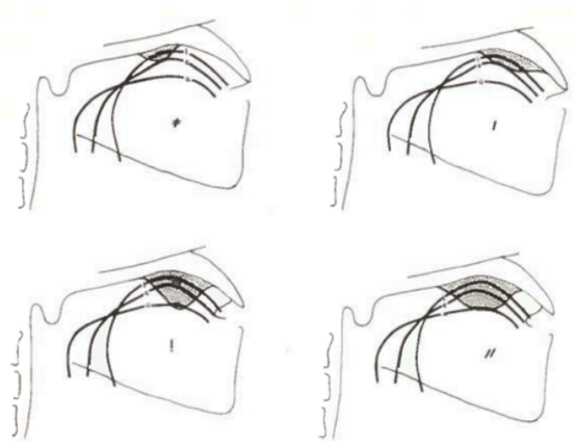

Figure 3: Tongue positions for the suction cavities [ǂ] [ǀ], [!], and [ǁ] prior to release (shaded areas) with the tongue positions of the vowels [i e a] superimposed (adapted from Traill 1985: 115, Fig. 27)

Finally, the tracings on Figure 4 (a-b) clearly show the intermediate articulatory position of [ɜ] between [a] and [i]: the tongue in [ɜ] is raised away from [a] and towards [i], without reaching the height of [e]. Interestingly, "if one examines the position of the root of the tongue for [ɜ], one sees that there is a wider pharynx for [ɜ] than for [e]. The largest assimilatory change from the tongue position of [a] thus lies in advancing the tongue root toward the tongue root position of [i]" (Traill 1985: 73-74). In other words, this assimilation clearly involves both raising of the tongue dorsum, and fronting (or absence of retraction) of the tongue root: the acoustic diagonal identified in Figure 2 above is mirrored in articulation by a diagonal that takes the tongue body from a low and retracted position for [a], through an intermediate position for [ɜ] and [e], to a high and advanced position for [i].

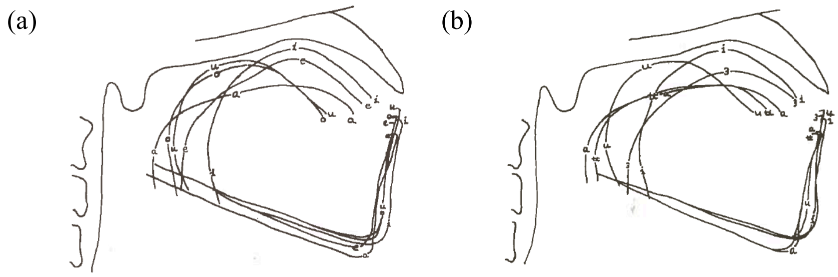

Figure 4: Tongue and jaw positions for one subject, traced from a single frame during the steady state production of the vowels (a) [i e a o u] as first vowel in the demonstrative **ti'i**, **ta'a**, **te'e**, **tu'u**, and the nonsense form **to'o**; (b) [ɜ ʉ] in **tán** [tɜ́n] 'to it' and **tùm** [tʉ̀m] 'swallow', plotted against the positions for [i a u] (Traill 1985: 73-74, Fig. 7 & 8)

The fact that pharyngealized [aˤ] and strident [a̰ˤ] are not affected by the high/front assimilation also has a clear articulatory basis: their articulation involves a significant retraction and lowering of the tongue root (in particular for the strident vowels, which involve aryepiglottal trilling), which is antagonistic with fronting and raising (see Traill 1985: 75-77, Fig. 9 & 11a). The assimilatory pattern described above is thus clearly rooted in both articulation and perception.

4. Intervening consonant in complex onset

Finally, it must be noted that $C_{[+]}$ clicks co-trigger the assimilation even when separated from the target vowel by a consonant, in the case of $C_{click}C$ initial clusters, as shown in (11)-(13) below.

(11) /A/ → [ɜ] / $C_{[+]}$_Ci

Cl. + ʔ	/ǂʔÁli/	[ǂʔɜ́li]	'flick off from'	

(12) /A/ → [i] / $C_{[+]}$_i

Cl. + ʔ	/|ʔÀi/	[|ʔìi]	'lover'	cf. pl. **|ʔàba-tê**
Cl. + h	/ǂhÁi/	[ǂhíi]	'posterior aspect of a body part'	cf. pl. **ǂhába-tê**
Cl. + q'	/|q'Ài-sà/	[|q'ìi-sà]	'backwards, behind'[12]	
Cl. + qʰ	/|qʰÁi/	[|qʰíi]	'buffalo'	cf. pl. **|qʰába-tê**

(13) /A/ → [e] / $C_{[+]}$_e

Cl. + ʔ	/|ʔÁ-e/	[|ʔée]	'chase-CLASS.3ii'	cf. deverbal form **|ʔáã**
Cl. + q	/|qÁe/	[|qée]	'Nama'	cf. pl. **|qám**
Cl. + qʰ	/ǂqʰÁe/	[ǂqʰée]	'bush sp.'	cf. pl. **ǂqʰám**

However, the seven consonants that can occur as the second element in a stem initial cluster [q qʰ q' χ q͡χ' ʔ h] do not all behave alike. While [ʔ h q q' qʰ] are inert and

[12] This word is spelt **|q'ìi-sà** in the dictionary. I have taken the liberty to interpret V_1 as being underlyingly /A/, in accordance with the analysis adopted here.

transparent to the assimilatory effect exerted by the initial consonant, as shown in (11)-(13) above, the uvular fricative [χ] and ejective affricate [qχ’], on the other hand, block the effect of the preceding $C_{[+]}$: [$C_{[+]}$χ] and [$C_{[+]}$q͡χ’] clusters behave like $C_{[-]}$ consonants.

The reason for this is likely due to the length of these two consonants: “the duration of [the intervening consonant] varies but may be considerable, from a mean 28ms for the uvular accompaniment [q], to a mean 88ms for the glottal stop accompaniment [ʔ], to a mean of 130ms for the velar fricative accompaniment [x]” (Traill 1997: 108; cf. also Traill 1993). That fricatives and affricates should be longer than stops is in no way surprising, and the longer the second consonant in a C_{click}C cluster, the more time the front part of the tongue has to move towards the low target position necessary for the articulation of the following [a] (taken to be the default realization of /A/). There seems to be a length threshold beyond which the intervening consonant blocks the effect of C_1 on the target vowel: [ʔ, q, q’, q^h, h] are below the threshold, [q͡χ’, χ] above.

Finally, it must be noted that this cumulative raising and fronting coarticulatory and/or assimilatory pattern in East !Xoon looks entirely “natural.” Whether it is phonological or can be reduced to phonetic implementation is, however, unclear. To answer this question, we need more reliable data on whether the effects noted are categorical or gradient (or either, depending on context), how much intra- and inter-speaker variation there is, or what role frequency plays. The description presented above is thus only preliminary, and requires both more data and further analysis.

5. The case of G|ui

A similar pattern is attested in G|ui (Khoe-Kwadi; Nakagawa 1996, 2006, 2010), but it appears to be less phonetically natural, more deeply phonologized than in Taa. The G|ui vowel inventory is presented in Table 7: the same five basic vowel qualities as in Taa are attested, as well as the same underspecification of V_1 for dorsal features. The only difference is that G|ui has only one non-modal phonation type: pharyngealization.

The different phonetic realizations of V_1 /A/ are relatively similar to Taa: [a, a̰, ɐ, e, i], illustrated in (14)-(20) (ignoring nasalization). They are distributed along the same diagonal between low back [a] and high front [i]. The conditioning of the realization of /A/ is however different from Taa in non-trivial ways. Indeed, the set of consonants co-triggering raising and fronting ($C_{[+]}$) includes not only laminal consonants, as in Taa, but also velars (except ejective [k’] and nasal [ŋ]), and labial consonants, as shown in Table 8, where the $C_{[+]}$ consonants are shaded.

I will first look at assimilatory patterns targeting /A/ in O_V_2 context. In G|ui, like in Taa, V_2 [i] is strong enough to fully assimilate a previous /A/, as shown by the example in (14), where the glottal plosive /ʔ/ in root onset position is articulatorily neutral. Whether [e] has the same effect is unknown, for lack of data.[13]

[13] Examples in this section are taken from Nakagawa (1996) and Nakagawa et al. (2004).

		V_1 features		V_2 features				V_1 allophones
		[round]	[phar]	[high]	[low]	[back]	[nasal]	
V1	/A/	–	–					[a a̤ ɐ e i ã ĩ]
	/U/	+	–					[u o ũ]
	/aˤ/	–	+					[aˤ ãˤ]
	/uˤ/	+	+					[uˤ ũˤ]
V2	/i/			+	–	–	–	
	/e/			–	–	–	–	
	/a/			–	+	+	–	
	/o/			–	–	+	–	
	/u/			+	–	+	–	
	/ĩ/			+	–	–	+	
	/ã/			–	+	+	+	
	/ũ/			+	–	+	+	

Table 7: Distribution of vowel features in disyllabic roots in G|ui (after Nakagawa 2010)

	labial	alveolar	alv. affr. /palatal	palatal	dental	alveolar	palatal	lateral	velar	uvular	uvular-	glottal
Plain	p	t	t͡s	c	|	!	ǂ	‖	k	q		ʔ
Voiced	b	d	d͡z	ɟ	|̬	!̬	ǂ̬	‖̬	g	ɢ		
Vl. aspirated	pʰ	tʰ	t͡sʰ	cʰ	|ʰ	!ʰ	ǂʰ	‖ʰ	kʰ	qʰ		
Vl. ejective		t’	t͡s’	c’	|’	!’	ǂ’	‖’	k’	q’	q͡χ’	
Nasal plain	m*	n**			|̃	!̃	ǂ̃	‖̃	ŋ			
Fricatives		s								χ		h
Sonorants	w^{Cm}	r^{Cm}		j								
Plain+ ʔ					|ʔ	!ʔ	ǂʔ	‖ʔ				
Plain+ h					|h	!h	ǂh	‖h				
Plain+ q					|q	!q	ǂq	‖q				
+voice					|̬q	!̬q	ǂ̬q	‖̬q				
Plain+ qʰ					|qʰ	!qʰ	ǂqʰ	‖qʰ				
+voice					|̬qʰ	!̬qʰ	ǂ̬qʰ	‖̬qʰ				
Plain+ q’					|q’	!q’	ǂq’	‖q’				
Plain+ χ		t͡χ	ts͡χ		|χ	!χ	ǂχ	‖χ				
Plain+ q͡χ’		tq͡χ’	t͡sq͡χ’		|q͡χ’	!q͡χ’	ǂq͡χ’	‖q͡χ’				

**attested in O, C_m, coda* ***attested only in C_m and coda* ^{Cm}*attested only in C_m*

Table 8: The consonant system of G|ui (Nakagawa 2006: 109, 139; 2010)

(14) /A/ → [i] / (ʔ)_i
/ʔĀi/ [ʔīi] 'to seem'

Contrary to Taa, palatal consonants in onset position are also strong enough to fully assimilate /A/ to [i], irrespective of the neighboring consonants or vowels, as shown (15).

(15) /A/ → [i] / Pal_
/cÁé/ [cíé] 'to be standing'
/ɟÀā/ [ɟìā] 'owner'
/ɟÀō/ [ɟìō] 'to burn'
/cÁbè/ [cíbè] 'to flash the lightning'
/ɟÁná/ [ɟíná] 'to flatter'

/A/ is also fully assimilated to [i] or [e] when wedged between a $C_{[+]}$ and [i] or [e]:

(16) /A/ → [i] / $C_{[+]}$_i
/d͡zÁì/ [d͡zíì] 'to tire'
/|Áī/ [|íī] 'song'
/ǂ̃Àī/ [ǂ̃ìī] 'to be skillful'
/bÁī/ [bíī] 'plant sp.'
/kÁī/ [kíī] 'to choose fat game'

(17) /A/ → [e] / $C_{[+]}$_e ($C_{[+]}$ ≠ Pal, cf. (14))
/t͡sÁé/ [t͡séé] 'to work'
/|Áé/ [|éé] 'wildebeest'
/ǂÁē/ [ǂéē] 'ear'
/bÁè/ [béè] 'to cause to fail'
/kÁrē/ [kérē] 'to return'

Interestingly, /A/ is realized [e] when wedged between a $C_{[+]}$ and the high back vowel [u], as illustrated in (18).[14]

(18) /A/ → [e] / $C_{[+]}$_u ($C_{[+]}$ ≠ Pal, cf. (14))
/t͡sʰÁū/ [t͡sʰéū] 'hand, finger'
/|Áu/ [|éū] 'one's character'
/ǂ̬Áú/ [ǂ̬éú] 'kori bustard'

This seems to indicate that [u] is a weaker trigger than [i]: its assimilatory effect seems to be a compromise between the two antagonistic forces of its articulatory characteristics: its height militates for raising, but the low position of the tongue

[14] Note that sibilant fricatives and affricates seem to have a stronger effect than laminal clicks, triggering higher and more fronted realizations of /A/ as [e] ~ [e̝] ~ [ɪ] event when followed by [u] in at least three cases: /d͡zÁú/ [dzéú ~ d͡zíú] 'to keep company', t͡sÁú [tséú ~ t͡síú] 'to get fat', sÁū [séū ~ síū] 'to set a dog on something' (Nakagawa, p.c.).

dorsum and tip necessary for its articulation prevents it from raising /A/ all the way to [i] (assuming [i] is more fronted than [e]).

Finally, like in Taa, $C_{[-]}$ consonants ([!], [‖], uvulars and ejective [k’]) have a strong counteracting effect on the assimilatory strength of a high V_2: the observed raising in $C_{[-]}$__$V_{[+high]}$ context is limited to [ɐ] ($C_{[-]}$ = apical click series [! ‖]) and [a̙] ($C_{[-]}$ = uvulars and [k’]).[15]

(19) /A/ → [ɐ] / {!, ‖}_V[+high]
/!̃Áī/ [!̃ɐ́ī] ‘lump’
/‖ʰÁù/ [‖ʰɐ́ù] ‘to clear away’

(20) /A/ → [a̙] / {(CLICK)Q, k’}_V[+high] (Nakagawa p.c.)
/|qʰÁī/ [|qʰá̙ī] ‘stick sp.’
/|̬qÁū/ [|̬qá̙ū] ‘cloud sp.
/k’Ai/ [k’a̙i] ‘to belch’

/A/ is realized [a] in every other O__V_2 context, i.e. when V_2 is [o] or [a] (except if O is palatal, cf. (14)), and in $C_{[-]}$__e. This is summarized in Table 9, where gradient shading indicates the degree of the coarticulatory/assimilatory effect of the environment.[16] Table 10 shows the trigger strength hierarchy (in OVV roots only).

	_V_2 (C_m = Ø)				
	i	u	e	o	a
1. Palatal	i	i	i	i	i
2. Alveolar + ǀ and ǂ series	i	e	e	a	a
3. Labial	i	?	e	?	a
4. Velar	i	?	?	a	a
6. ! and ‖ series	ɐ	ɐ	a	a	a
7. (CLICK)Q, k’	a̙	a̙	a	a	a

Table 9: realization of V_1 = /A/ in O__V_2 contexts in Gǀui

The intervening C_m also plays a role in this assimilatory pattern. In the interest of length, I will not go into too much detail here, and give only one example: $C_{[+]m}$ [r], [n], [b], and [m] help non-palatal $C_{[+]}$ change /A/ to [e] even before non-high back [a] or [o], as illustrated in (21).[17]

[15] Hirosi Nakagawa (p.c., 22 Dec. 2015)

[16] For lines 1-2 and 6-7, the data and generalizations are borrowed from Nakagawa (1996). For lines 3-5, the data are from Nakagawa et al.’s (2004) unpublished Gǀui dictionary. “?” indicates lack of data. The shading (or lack thereof) of the four cells containing “?” is an extrapolation based on Nakagawa’s (1996) generalizations.

[17] The fact that /A/→ [e] in (21) occurs irrespective of the place of articulation of Cm (whether coronal or labial) seems to indicate that this process is not triggered by the place of Cm, i.e. it might not be assimilatory/co-articulatory. One possible explanation, suggested by Hirosi Nakagawa, is that this process is rather triggered by the prosodic shape of the template

high/front		low/back
strong ↑	Palatal__	
	__i	
	__u	
	__e	
weak	Alveolar, ǀ, ǂ, Labial, Velar__	↓
		strong
	__a, __o	
	!__, ǁ__	
	(CLICK)Uvular, k'__	*weak*

Table 10: Assimilatory strength in Gǀui OV_1V_2 roots

(21) /A/ → [e] / $C_{[+]}$_C_m{a, o} ($C_{[+]}$≠Pal, cf. (14))[18]

/d͡zÀrà/ [d͡zèrà] 'to be still small (fruit)'
/ǀ̌Àrō/ [ǀ̌èrō] 'ostrich'
/ǀ̃Ànā/ [ǀ̃ènā] 'dregs'
/ǀÁbá/ [ǀébá] 'to wear on the head'
/kÁmá/ [kémá] 'time, season'

This is summarized in Table 11. The only difference between Table 9 and Table 11 is in the six cells enclosed in the dotted line, representing the effect of [r n b m] in a C_m position.

		_C_mV_2 (C_m = [r n b m])				
		i	u	e	o	a
1.	Pal_	i	i	i	i	i
2.	Alv + ǀ and ǂ series_	i	e	e	e	e
3.	Lab_	?	?	?	?	?
4.	Vel_	i	?	?	?	a,e
6.	! and ǁ series_	a	a	a	a	a
7.	(CL)Q, k'_	a	a	a	a	a

Table 11: realization of V_1 = /A/ in O__C_mV_2 contexts

Finally, similarly to Taa, only a subset of intervening consonants in complex onsets are neutral or transparent to the assimilatory pattern, the others having a backing or blocking effect. However, contrary to Taa, it is not the length, but the articulatory properties of the intervening consonant that determine whether it is neutral/transparent or has a backing or blocking effect (Nakagawa 2006). The

$OV_1C_mV_2$, in which V_1 is phonetically always short. The shortness of V_1 in this template may cause undershoot of V_1 in height. /A/ → [e] in (21) would thus be multi-triggered, O being responsible for the fronting effect, and Cm for raising.

[18] Note that once again, sibilant fricatives and affricates seem to have a stronger effect: /sÁrō/ [sérō ~ sírō] 'to refuse', /dzÁmā/ [dzémā ~ dzímā] 'to look with disgust on one's face', /dzÀrō/ [dzèrō ~ dzìrō] 'to pick up a lot of small things' (Nakagawa, p.c.).

differences between the two languages are summarized in Table 12, where the dotted line in each of the language columns separates the blocking intervening consonants from the neutral ones: glottal vs. uvular in G|ui, length threshold between [q^h] and [qχ’] in Taa.

		G|ui	Taa	
Glottal	ʔ	neutral/transparent	neutral/transparent	*min length*
	h	neutral/transparent	neutral/transparent	↓
Uvular	q	backing/blocking	neutral/transparent	
	q’	backing/blocking	neutral/transparent	
	q^h	backing/blocking	neutral/transparent	
	qχ’	backing/blocking	backing/blocking	
	χ	backing/blocking	backing/blocking	*max length*

Table 12: Neutral/transparent vs backing/blocking effect of intervening consonants in complex onsets in East !Xoon and G|ui

6. Analytical issues and relevance for phonological theory

6.1 Analyses proposed so far

In trying to account for the East !Xoon facts with articulatory features, Traill (1985) encounters many problems. He first notes that this cannot be done in Chomsky and Halle’s (1968) feature system. He then notes that “the role played by [ǀ] and [ǂ] in [the assimilation patterns] seems to be that these two clicks facilitate the raising process and this points to a categorization of them as [+high].” His proposal is thus to analyze $C_{[+]}$ consonants as [+high], and $C_{[–]}$ as[–high]. A further specification is however needed: the feature [±high] is only relevant for the front part of the tongue. Indeed, [!] And [ǁ] are also high by virtue of the velar closure; however, due to their apical articulation, the front part of the tongue is overall in a lower position than for the laminal articulation of [ǀ] and [ǂ], which is precisely what is relevant for the raising/fronting assimilation.

Note that it is even more difficult to account for the G|ui data using only articulatory features. We saw in section 5 that $C_{[+]}$ consonants in G|ui do not constitute a natural class from an articulatory point of view: labial and velar consonants pattern with alveolar laminal consonants, despite being very different, both articulatorily and perceptually (labials and velars are grave, alveolar laminal consonants are acute). It is also noteworthy that phonetic natural classes do not always behave alike, as is the case with velars: [k] and [k^h] have an (unexpected) mild fronting/raising effect, while [k’] has a strong lowering/backing effect (more in line with the articulatory and perceptual properties of velar consonants). Finally, [u] acts as a co-trigger of raising and fronting, as in /ǂAu/ → [ǂeu], despite (i) not being a front vowel, and (ii) not involving a high position of the front part of the tongue (as per Traill’s definition of [±high]).

Ten years after his initial articulation-based proposal, Traill (1995) proposes a perceptual analysis crucially based on the feature [±grave] (Jakobson et al. 1952;

Jakobson 1968). Front vowels and laminal (= $C_{[+]}$) consonants in East !Xoon are acute, i.e. [–grave], while back vowels and non-laminal (= $C_{[-]}$) consonants are [+grave]. The double-sided vowel assimilation pattern described above can thus be analyzed as in (22):

(22)	a	→	[i]	/	$C_{[+]}$	__	I
	|		|		|		|
	[+grave]		[–grave]		[–grave]		[–grave]

However, this analysis runs into at least two problems. First, it only explains cases of double-sided assimilation involving two triggers, which, as we saw in section 2, constitute only a subset of the East !Xoon data. Secondly, it models a categorical effect, and not the gradient effects that are at work in East !Xoon.

Finally, Bradfield's (2014:13; 32-37) recent reanalysis of this pattern mostly follows Traill's (1985) generalizations, by distinguishing laminal clicks [ǀ ǂ] from non-laminal ones by their [high] and [back] specifications. The cumulative effects are somehow accounted for in a two-step process (similar to that suggested by Traill's short summary in his 1994 dictionary): "A first-mora plain, breathy or creaky ‹a› is raised to [ɜ] when the second mora contains ‹i›, or is a nasal, and the word starts with a dental non-click or ‹ǀ ǂ›" (moderate raising); "it is further raised to [i] when the second mora is just ‹i›" (full raising) (p.13). However, this generalization is only a rough approximation of the East !Xoon pattern, as we saw in section 3, and falls short of accounting for the complexity and the gradience of East !Xoon raising/fronting assimilation. Some of Bradfield's generalizations also do not concord with mine, although we both draw from the same source (mostly Traill 1994). The independent effect of [i] seems to always be full assimilation to [i] and not partial raising to [ɜ] in Traill's (1985, 1994) data (cf. (5)). C_m is not transparent (compare (2)-(3) and (4)), although, as we saw, its counteracting effect is perhaps not due to coarticulation. Finally, uvular C_2's do not all block "full A-raising": only [χ] and [q͡χ'] do (cf. (12) and (13)). It must be said here that extracting these generalizations from Traill's data is not an easy task, and the final picture, as can be gathered from section 3, remains somewhat blurry on certain points.

It is also important to note that Bradfield's goal is not to explain or account for this pattern, but rather to show that his concept of "concurrent phoneme", applied to the entire segmental phonology of East !Xoon, is compatible with expressing such assimilation rules, and might help shed light on otherwise unexplained aspects for /A/ raising. The main advantage of the concurrent analysis in this case is that it seems to offer an explanation of the transparency of intervening uvular C2 (/q'/). Indeed, if the click in C1 and the uvular in C2 position are concurrent, i.e. not phonologically ordered or linearized, then the uvular C2 cannot be said to intervene between the laminal click causing the raising and the target vowel /A/: "the target vowel is immediately adjacent to both the click and the accompaniment." A problem for this analysis is of course the fact that there are "opaque/blocking" uvular C2, and that, as we saw in section 4, it is the length of the intervening uvular C2 that seems to be the crucial criterion deciding whether it is transparent or opaque.

This is not explained by the concurrent analysis, where all C2's would have the same status. Furthermore, his two rules (moderate and full raising) are mostly descriptive, and do not explain crucial aspects of /A/-raising, such as the gradience at work, as we said, but also the teamwork effect, which is only stipulated in the rules (both double-sided). The fronting effect is also left unexplained. This, of course, is perfectly acceptable for Bradfield's purpose. But an analysis of this assimilatory pattern must account for both raising and fronting, and Bradfield's hypothesis of a late rule "filling in [-back]" does not seem to be sufficient, in so far as it does not account for the gradient differences noted here between the potential co-triggers.

6.2 Challenges for phonological theory

The data described in this paper is potentially problematic for phonological theory in two ways. First, it seriously poses the question of the potential role of phonetics in phonological computation and the possibility of phonetic grounding in phonology. As mentioned above, the East !Xoon data are phonetically natural, i.e. the phonetic grounding (be it synchronic or historical) is clearly identifiable. The only problem is determining what is phonetic (i.e. purely mechanic), and what is phonological, i.e. part of the abstract sound system, determined by abstract rules or constraints. Indeed, while the weakest effects in Table 6 could easily be construed as coarticulation occurring in the (post-phonological) phonetic realization, the strongest effects definitely look like cases of systematic and unambiguous full assimilation of /A/ to [i] or [e], and have all the appearance of a categorical phonological pattern. Traill noted the problem posed by the complexity of the relationship between phonological specification and phonetic detail in East !Xoon, although he did not try to solve this issue: "optimal phonological specifications cannot meet the joint requirements of being non-redundant while at the same time being directly interpretable in terms of corresponding *n*-ary phonetic scales" (1985: 121).

The G|ui data, on the other hand, points to a non-phonetically grounded account (except perhaps the weakest effects, i.e. the [ɐ, a̟] realizations of /A/, which could be due to pure phonetic coarticulation), given the fact that the class of consonants triggering the cumulative raising/fronting effect do not form a phonetic natural class, as we saw.

The second challenge of the assimilatory effects described above is their cumulative and gradient nature. These effects constitute cases of "phonological teamwork", i.e. processes that involve multiple triggers, and complex, cumulative segmental interactions (Lionnet 2016). Of course, this is not a problem as long as such effects are only phonetic, and not phonological. However, if phonological, as seems to be the case in G|ui (and possibly also in East !Xoon, at least partly), one needs to account for the necessity of this multiplicity of triggers. Traill had already noticed that problem in his 1985 articulatory account, and sketched the beginning of a solution, although he never pursued it: "it would be necessary to formulate a rule involving *n*-ary values of the feature [high] which would show how [a] was subject to increasing degrees of assimilation when followed by or both preceded and followed by the [n-high] segments [i], [e], [ǀ], [ǂ]"(1985: 114).

As I have shown elsewhere (Lionnet 2016: 167-176), the ganging effects modeled by either Local Constraint Conjunction (Smolensky 1993, 1995) in Optimality Theory (Prince and Smolensky 1993/2004), or weighted constraint models such as Harmonic Grammar (Legendre et al. 1990; Smolensky and Legendre 2006) can only model categorical processes, and not cumulative effects similar to the ones observed in V_1 raising/fronting in KBA languages.

A possible solution is to resort to gradient representations, e.g. phonetically grounded "subfeatures" representing various degrees of coarticulatory strength (Lionnet 2016, 2017). While nothing seems to preclude a subfeatural account of East !Xoon, where the fronting/raising pattern looks entirely phonetically grounded, it is a little harder to see how to implement a similar analysis of the Gǀui data, where phonetic grounding does not seem to be an available option, at least not for the entire data. This of course can only be determined with certainty when we have precise data on coarticulation and variation in both languages, and any proposed analysis will remain preliminary and hypothetical until tested against such data.

4. Conclusion

In conclusion, the principles governing the realization of V_1 in KBA languages involve very subtle cumulative effects arising from the interaction of up to three segments. These very complex principles vary greatly across languages, as clearly shown by the comparison between East !Xoon and Gǀui. It is not clear whether the processes at work are purely phonetic or (at least partly) phonological in some of these languages. Such complex, cumulative segmental interactions involving various degrees of assimilatory strength seem to require new, dedicated scalar representations, e.g. multi-valued features, subfeatures, etc. More research is needed in both the phonetic and phonological description of KBA languages, and in the still understudied question of gradience in phonology —both from a typological perspective (accruing the number of attested similar processes), and from a theoretical one (developing appropriate analytical tools, interrogating our understanding of how phonological computation works).

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