Tonal Exchange *via* Subcategorizing Floating Tones: Modeling Two Kinds of Flip-flop in Khoekhoe

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1 Introduction

One long-standing question in (morpho)phonology is what is a possible alternation? In other words, what is considered a natural alternation and derivable from standard phonological tools, and what would be considered unnatural and perhaps underivable? To demonstrate this, let us sketch three toy patterns with a phonologically symmetrical vowel inventory /i y e ø ɨ u a o/ (Table 1). Within each toy pattern below, vowels appear in input → output alternations which apply in a specific (morpho)phonological environment. For example, Table 1a shows a simple neutralization pattern whereby back vowels become their front counterparts in some environment (and front vowels remain front). Such patterns are common in the world's vowel harmony systems, and we label them 'possible'. In contrast, Table 1b shows what we take to be an impossible pattern, whereby each of the eight vowels appears 'scrambled' and clear natural classes do not emerge. In this system, where i → e exhibiting lowering, in the same environment ɨ → y exhibiting fronting and rounding, *etc*. While the different statuses of Table 1a versus 1b may strike us as intuitive, 1c is less so. Here, in the same environment all front vowels become back, but all back vowels become front. Is such a pattern possible?

a. Possible		b. Impossible		c. Possible?	
i → i	ɨ → i	i → e	ɨ → y	i → ɨ	ɨ → i
y → y	u → y	y → ø	u → ɨ	y → u	u → y
e → e	a → e	e → u	a → i	e → a	a → e
ø → ø	o → ø	ø → a	o → o	ø → o	o → ø

Table 1: What is a natural (morpho)phonological alternation?

Patterns akin to Table 1c are referred to as (morpho)phonological EXCHANGE, sometimes also called polarity, reversals, or toggling (Meinhof 1912; Chomsky & Halle 1968; Anderson & Browne 1973; Andersen 1989; Baerman 2007; Wunderlich 2012; de Lacy 2012; *inter alia*). We can schematize exchange as in (1), which can be rendered with bivalent (1a) or monovalent features (1b), or as the absence or presence of a feature (1c).

(1) Exchange schema

	a.		b.		c.
	[+F] → [–F]		[F] → [G]		[F] → ∅
	[–F] → [+F]		[G] → [F]		∅ → [F]

Is exchange empirically attested, and if so, how should it be modeled? One recent and empirically well-supported example is 'glottal toggling' in Itunyoso Triqui (DiCanio *et al.* 2020): in certain morphological contexts (e.g. first person singular), stems without coda /ɦ/ add one, but stems with one delete it (i.e. anĩː → anĩɦ, but anĩɦ → anĩː – tone omitted). In response, de Lacy (2020) sketches two positions one could take to account for this pattern. The first posits a dedicated EXCHANGE MECHANISM to derive exchange. Representative examples exist both in rule-based models (e.g. SPE-style [αF]-notation in 2a – Gregersen

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1974) and in constraint-based models (e.g. Antifaithfulness in 2b – Alderete 2001). Both of the formalizations in (2) pertain to purported voicing exchange in Luo triggered by certain morphological contexts. And in both models, there is an overt and explicit requirement for a feature to *not* be identical in the output as it was in the input. In this way, exchange is a direct consequence of the exchange mechanism and is not derivable from other properties of the (morpho)phonological grammar.

(2) Dedicated exchange mechanisms

a. Exchange rule (Gregersen 1974:106)

$$\begin{bmatrix}\text{-voc}\\ \text{+con}\\ \alpha\text{voiced}\end{bmatrix} \rightarrow \begin{bmatrix}\text{-}\alpha\text{voiced}\end{bmatrix} \;/\; \_\_ \begin{bmatrix}\text{Pl -}E\\ \text{App}\end{bmatrix}$$

b. Antifaithfulness constraint (Alderete 2001:211)

¬IDENT[voice]: It is not the case that corresponding segments agree in the feature [voice]

This type of analysis can be contrasted against a second type advocated by de Lacy (2020), which rejects the requirement of a dedicated exchange mechanism. Under this alternative, exchange is an incidental outcome of several independently motivated components of the grammar, such as referring to independently observable phonotactic generalizations. As emphasized by de Lacy (2020), this alternative requires some combination of rule-ordering or stratal constraint-based architecture. This is because exchange involves a kind of opacity which is not strictly-speaking compatible with a purely non-derivational analysis *à la* classical Optimality Theory (OT – Prince & Smolensky 2004) with a single input-output mapping (or, as de Lacy mentions, classical OT would need some dedicated opacity mechanism like Sympathy Theory – McCarthy 1999). Under this type of analysis, de Lacy emphasizes that while a language "might descriptively have an exchange, it does not follow that a phonological module is capable of an exchange transformation" directly (p. 36).

All else being equal, the latter type of analysis would be preferred, as it would involve a less powerful (more restricted) grammar. What then are the precise mechanics by which exchange comes about if a dedicated mechanism is forbidden? The goal of this paper is to investigate one solution deriving exchange without an exchange mechanism, found in an area which has surprisingly been overlooked in the exchange literature: TONAL EXCHANGE. Tonal exchange, too, exemplifies the schema in (1), but the relevant feature here is a toneme (e.g. H or L, *etc*.) or tonal feature (e.g. [+raised], *etc*.). Tonal exchange is well-established in the tone literature, primarily from Asian tone systems (Yue-Hashimoto 1986; Mortensen 2006) but some African systems as well (Odden 2009). In what follows, we highlight an additional example of tonal exchange in the African language Khoekhoe (Haacke 1999a), which we incorporate into the above theorical debate.

Specifically, Khoekhoe causative morphology triggers what specialists have called a kind of 'FLIP-FLOP' (borrowing the term from Wang 1967): in this morphological environment, stems without an underlying mid tone add one (e.g. L → LM) but stems which already contain an underlying mid delete it (e.g. LM → L). We shall argue that tonal exchange here is derived via a FLOATING TONE which is endowed with a PROSODIC SUBCATEGORIZATION frame requiring that it be stem-external. In short, the causative M triggers delinking of the stem's M (but crucially not deletion), while its stem-external requirement prevents it from actually appearing within the stem itself in the context of another M. The result is what we call 'mutual dissimilation'. In total, both floating tones and subcategorization frames are independently required representational devices, and these can derive exchange without the need for an additional dedicated exchange mechanism.

Following this introduction, this paper is organized as follows. Section 2 lays out the relevant Khoekhoe data. Section 3 then presents an analysis of the data broken down into three parts: underlying representations, the role of floating tones, and the role of subcategorization. Section 4 provides discussion, and section 5 provides a conclusion.

2 Khoekhoe data

Khoekhoe – conventionally /kwekwe/, ISO 639-3 code [naq], Glottocode [nama1264] – is a national language of Namibia in Southern Africa.[1] Genealogically, it belongs to the Khoe-Kwadi family (Güldemann & Vossen 2000), though it is often identified as ‘Khoisan’ (now understood as an areal grouping). With roughly 200,000 speakers (Brenzinger 2013:16), it is undoubtedly the largest ‘Khoisan’ language currently spoken.

Khoekhoe’s tone system has been extensively documented and analyzed over the last 100 years, both its synchrony and diachrony (Schultze 1907; Beach 1938; Haacke 1976, 1992, 1999a, 1999b, 2008; Hagman 1977, 2002; Haacke & Eiseb 2002; Elderkin 2004, 2008, 2013; Brugman 2009; Kusmer 2020a, 2020b, 2021). From this literature, there is consensus on the underlying tone contrasts: stems bear one of six primary TONAL MELODIES which are realized on a four-height pitch scale. Each of these melodies is distributed across a bimoraic stem, consisting of one of the following patterns: two short vowels, a short vowel plus sonorant consonant, a long vowel, or a diphthong. The bimoraic stem is in fact the canonical stem shape across ‘Khoisan’ languages (Nakagawa *et al.* 2023), and where relevant we denote the bimoraic stem as a constituent $\{\mu\mu\}_\Sigma$ (where Σ stands for ‘stem’).

We repeat a six-way minimal set from Haacke (2008), in Table 2. Each of the six melodies is notated with a referential letter (e.g. A), a conventional label (e.g. ‘Top’), its approximate pitch height (where 4 is highest and 1 is lowest), the pitch range where the melody is realized across the two stem moras (e.g. both at [4], or the first at [4] and the second at [3], *etc.*), an example stem showing its typical realization(s), and finally the word which contains the stem and its meaning (the -s suffix is a separate person/gender/number marker on nouns). We render word transcription as from the original source, with its conventional tone diacritics; these are always italicized.

Melody	Label	Height	Pitch range	Stem example	Word	Meaning
A	Top	4	[44~43]	!’o^{4}m^4- ~ !’o^{4}m^3-	*!ő́ḿs*	‘fist’
B	Intermediate	3	[33~32]	!’o^{3}m^3 ~ !’o^{3}m^2	*!óm̀*	‘coagulate’
C	Level	2	[22]	!’o^{2}m^2	*!òm̀*	‘force out’
D	Bottom	1	[11~12]	!’o^{1}m^1 ~ !’o^{1}m^2	*!ȍm̀*	‘bump’
E	Lower-Rise	12	[12~13]	!’o^{1}m^2- ~ !’o^{1}m^3-	*!ȍḿs*	‘udder’
F	Higher-Rise	24	[24~34]	!’o^{2}m^4- ~ !’o^{3}m^4-	*!òm̋s*	‘pollard’

Table 2: Six stem-level tone melodies of Khoekhoe (data from Haacke 2008:158)

Outside of these six stem melodies, other logically possible melodies are marginal or unattested.

A schematic diagram of the average frequencies (in Hertz) of the six melodies is provided Figure 1, extrapolated from Haacke (1999a). The ‘onset’ pitch of the four non-contour tones Top [4], Intermediate [3], Level [2], and Bottom [1] is clearly distinctive, but each slants towards a middle neutral pitch on average. In contrast, the two contour tones Higher-Rise [24] and Lower-Rise [12] show a sudden “marked change of inclination about half-way” (p. 96), with a very sharp ascent.

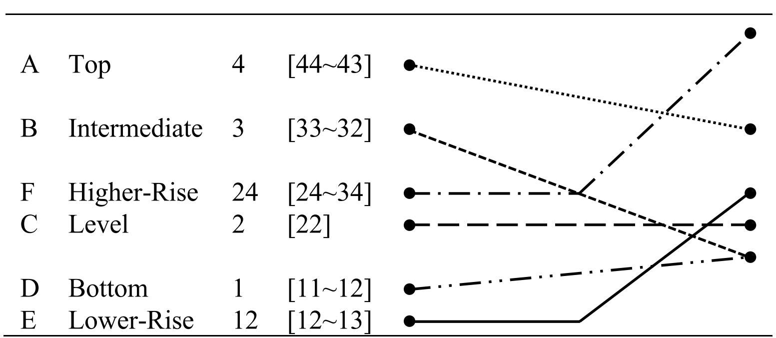

Figure 1: Schematic phonetic realizations of the six melodies (extrapolated from Haacke 1999a:97)

As all Khoekhoe researchers agree, there are three primary tone processes which systematically alter

[1] Khoekhoe is also called ‘Khoekhoegowab’ (approximately [kxʰȍèkxʰȍèkȍβàp]), or referred to by various dialect names such as ‘Nama’, ‘Damara’, ‘ǂĀkhoe’, ‘Haiǁom’, among others.

these citations melodies in context: weak flip-flop, strong flip-flop, and phrasal tone sandhi. This is summarized in Table 3. In the sections to follow, we describe and analyze the weak and strong flip-flop patterns, but do not address phrasal tone sandhi, which we view as an orthogonal process (see Kusmer 2020a, 2020b for details).[2]

Melody	Label	Citation		Weak flip-flop	Strong flip-flop	Phrasal tone sandhi
A	Top	4	→	24	24	3
B	Intermediate	3	→	2	2	21
C	Level	2	→	2	3	2
D	Bottom	1	→	12	12	21
E	Lower-Rise	12	→	12	1	12
F	Higher-Rise	24	→	24	4	2

Table 3: Three primary tone processes in Khoekhoe altering citation melody

2.1 *Neutralization via weak flip-flop* Weak flip-flop (Brugman 2009) – also called 'unilateral flip-flop' (Haacke 1999a) – is a tone alternation which results in the partial neutralization of the six melodies to just three: Higher-Rise [24], Level [2], and Lower-Rise [12]. This kind of flip-flop is quite common and found in many morphological contexts in Khoekhoe. One productive trigger of weak flip-flop is the applicative suffix *-bȁ* APPL 'do for'. The six melodies are shown in Table 4, grouped based on their neutralization patterns. The Top [4] and Higher-Rise [24] merge to Higher-Rise (Table 4a), Intermediate [3] and Level [2] merge to Level (Table 4b), and Bottom [1] and Lower-Rise [12] merge to Lower-Rise (Table 4c). Changes are noted in bold in this table. Recall as well that the bimoraic stem is indicated in curly brackets with a subscripted sigma Σ (for 'stem').

a.	A	Top	4	ku^{4}ru^{4}	*kűrú*	'make'	→	{**24**}$_{\Sigma}$-1	{**ku^{2}ru^{4}**}$_{\Sigma}$-ba^{1}	*kùrűbȁ*	'make for'
	F	Higher-Rise	24	!na^{2}ri^{4}	*!nàrí̋*	'steal'	→	{24}$_{\Sigma}$-1	{!na^{2}ri^{4}}$_{\Sigma}$-ba^{1}	*!nàrí̋bȁ*	'steal for'
b.	B	Intermediate	3	o^{3}a^{3}	*óà*	'return'	→	{**2**}$_{\Sigma}$-1	{**o^{2}a^{2}**}$_{\Sigma}$-ba^{1}	*òàbȁ*	'return for'
	C	Level	2	sa^{2}ri^{2}	*sàrì*	'visit'	→	{2}$_{\Sigma}$-1	{sa^{2}ri^{2}}$_{\Sigma}$-ba^{1}	*sàrìbȁ*	'visit for'
c.	D	Bottom	1	!na^{1}ri^{1}	*!nàrì*	'drive'	→	{**12**}$_{\Sigma}$-1	{**!na^{1}ri^{2}**}$_{\Sigma}$-ba^{1}	*!nȁríbȁ*	'drive for'
	E	Lower-Rise	12	u^{1}ri^{2}	*ȕrí*	'jump'	→	{12}$_{\Sigma}$-1	{u^{1}ri^{2}}$_{\Sigma}$-ba^{1}	*ȕríbȁ*	'jump for'

Table 4: Weak flip-flop neutralizing six melodies to three (in context of *-bȁ* APPL – Haacke 1999a:142)

2.2 *Exchange via strong flip-flop* In contrast, strong flip-flop ('bilateral flip-flop' in Haacke) involves these same three pairs, but each appears with the other's melody. While strong flip-flop is not nearly as common as weak flip-flop, one context which regularly triggers it is causative reduplication -$◌^{2}◌^{1}$ CAUS 'make do'. In this construction, the root is reduplicated and the reduplicant appears after it which bears a uniform [21] melody. The root itself (the first component) undergoes strong flip-flop and shows MELODY EXCHANGE with its paired counterpart. For example, (2a) shows that the Bottom melody [1] becomes Lower-Rise [12] (the root in bold), while (2b) shows the opposite where Lower-Rise [12] becomes Bottom [1] in this same construction. Melody exchange is equally seen for the other pairs, as shown in Table 5 (whereby [4] ↔ [24] exchange values, and [3] ↔ [2] do as well).

(2) Causative reduplication triggering strong flip-flop, with [1] ↔ [12] exchange (Haacke 1999a:134)

a. !ho^{1}a^{1}-$◌^{2}◌^{1}$ → **!ho^{1}a^{2}**-!ho^{2}a^{1} (*!hȍà → !hȍá!hòȁ*)
bent-CAUS 'bend, curve (something)'

b. !ho^{1}ra^{2}-$◌^{2}◌^{1}$ → **!ho^{1}ra^{1}**-!ho^{2}ra^{1} (*!hȍrá → !hȍrà!hòrȁ*)
crippled-CAUS 'cripple, maim (someone)'

[2] Briefly, in Khoekhoe phrasal tonology, only "the leftmost word in each domain keeps its underlying tonal melody, while all other words have their melody replaced" with the sandhi melody in Table 3 (Kusmer 2020a:61).

a.	A Top	4	|no^{4}m^4	*|nőḿ*	‘smile’	→	{**24**}$_{\Sigma}$-21	{**|no^{2}m^4**}$_{\Sigma}$-|no^{2}m^1	*|nòm̋-|nòm̏*	‘make smile’
	F H-Rise	24	|no^{2}o^4	*|nòő*	‘measure’	→	{**4**}$_{\Sigma}$-21	{**|no^{4}o^4**}$_{\Sigma}$-|no^{2}o^1	*|nőó-|nòȍ*	‘estimate’
b.	B Interm.	3	so^{3}m^3-	*sóm̀-*	‘shade’	→	{**2**}$_{\Sigma}$-21	{**so^{2}m^2**}$_{\Sigma}$-so^{2}m^1	*sòm̀-sòm̏*	‘make shady’
	C Level	2	ko^{2}n^2	*gòǹ*	‘move’	→	{**3**}$_{\Sigma}$-21	{**ko^{3}n^3**}$_{\Sigma}$- ko^{2}n^1	*góǹ-gòn̏*	‘move to & fro’
c.	D Bottom	1	|na^{1}m^1	*|nȁm̀*	‘love’	→	{**12**}$_{\Sigma}$-21	{**|na^{1}m^2**}$_{\Sigma}$-|na^{2}m^1	*|nȁḿ-|nàm̏*	‘inspire to love’
	E L-Rise	12	!nu^{1}wu^2	*!nȕbú*	‘short’	→	{**1**}$_{\Sigma}$-21	{**!nu^{1}wu^1**}$_{\Sigma}$-!nu^{2}wu^1	*!nȕbù-!nùbȕ*	‘shorten’

Table 5: Strong flip-flop with melody exchange (context of causative reduplication – Brugman 2009:164)

3 Analysis

3.1 *Part I: Underlying representations* The first part of our analysis establishes the underlying representation of the six stem melodies in Khoekhoe, provided in Figure 2. We decompose the melodies as involving three tonemes H, M, and L, their combination forming stem-level contours, plus tonal underspecification (∅). The non-contour melodies Top [4], Level [2], and Bottom [1] are phonologically /H/, /M/, and /L/, respectively, whose sole tone spreads over both moras of the stem. The Intermediate melody [3] is analyzed as tonologically unspecified underlyingly (realized with a default intermediate pitch phonetically). Lastly, only ‘one-step’ rising contours are permitted: Lower-Rise [12] is analyzed as /LM/ and Higher-Rise [24] as /MH/ (A /LH/ contour is not permitted underlyingly, nor are any falling contours).

Label (Melody):	Top (A)	Intermediate (B)	Level (C)	Bottom (D)	Lower-Rise (E)	Higher-Rise (F)
Pitch:	[4]	[3]	[2]	[1]	[12]	[24]
Phonological representation:	H /\\ {μ μ}$_{\Sigma}$	∅ {μ μ}$_{\Sigma}$	M /\\ {μ μ}$_{\Sigma}$	L /\\ {μ μ}$_{\Sigma}$	L M | | {μ μ}$_{\Sigma}$	M H | | {μ μ}$_{\Sigma}$

Figure 2: Proposed underlying representations of the six stem melodies

Based on these representations, we can repeat the outputs of weak and strong flip-flop (FF) from Table 3 above but using H, M, and L tonemes, shown in Table 6.

Pairing	Melody	Label	Pitch	Phonology		Weak FF	Strong FF
a.	A	Top	[4]	/H/	→	MH	MH
	F	Higher-Rise	[24]	/MH/	→	MH	H
b.	B	Intermediate	[3]	∅	→	M	M
	C	Level	[2]	/M/	→	M	∅
c.	D	Bottom	[1]	/L/	→	LM	LM
	E	Lower-Rise	[12]	/LM/	→	LM	L

Table 6: Three primary tone processes in Khoekhoe altering citation melody

As can be discerned, the common element in all of these patterns is the addition or deletion of a M tone (first observed more or less by Haacke 1999a:103).[3] Under weak FF, a M can be understood to have been added for all melodies. The result is vacuous application if the melody already has a M, but creates an overt alternation if the melody lacked a M. The positioning of the M is subject to the requirement that only rising stem-level contours are allowed (thus it appears at the left edge with /H/ → MH but at the right edge with /L/ → LM). In contrast, strong FF involves the exchange of M: stems without one gain it, but those with M already lose it. A phonological analysis in terms of tonemes L, M, and H connects overtly to the structure-preserving neutralizing and exchanging which characterize these two FF processes.

3.2 *Part II: The role of floating tones* How should this addition/exchange of M be modeled? One component of our model is analyzing the triggering morphological contexts as sponsoring a floating M tone, which we conventionally denote with a circle Ⓜ (following Yip 2002 – for an overview of floating tones,

[3] See also parallel observations for flip-flop involving M in a related language G|ui (Nakagawa 2006:61ff.).

see Rolle, Hyman, & Lionnet *forthcoming*). For example, the applicative suffix *-bà* APPL 'do for' (from Table 4 above) would be rendered with a pre-linked L preceded by a floating Ⓜ, in Figure 3.

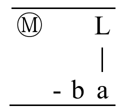

Figure 3: Representation of the applicative suffix *-bà* APPL 'do for' (weak FF trigger) with floating tone

A complete set of derivations involving this suffix is presented in Figure 4, showing how each of the six underlying melodies gets mapped to an output (taking the data from Table 4). This involves a two-step derivation: an Input → Intermediate mapping and an Intermediate → Output mapping. The intermediate level is where floating tones associate to a host within the stem (derived association is denoted by double checked lines ┆). For stems which lack M (Figure 4a/4c/4e), the floating Ⓜ docks according to the stem-level contour constraints already posited: it docks on the right with /L/ stems but to the left with /H/ stems (showing tonal metathesis), and with toneless stems it docks to the entire stem. In contrast, for stems which already have a M (Figure 4b/4d/4f) the floating tone coalesces with it, notated by the subscript letters (i.e. $Ⓜ_{i,j}$). After this at the output, linking to two tones is disallowed, resulting in delinking (the association lines in gray and crossed out).

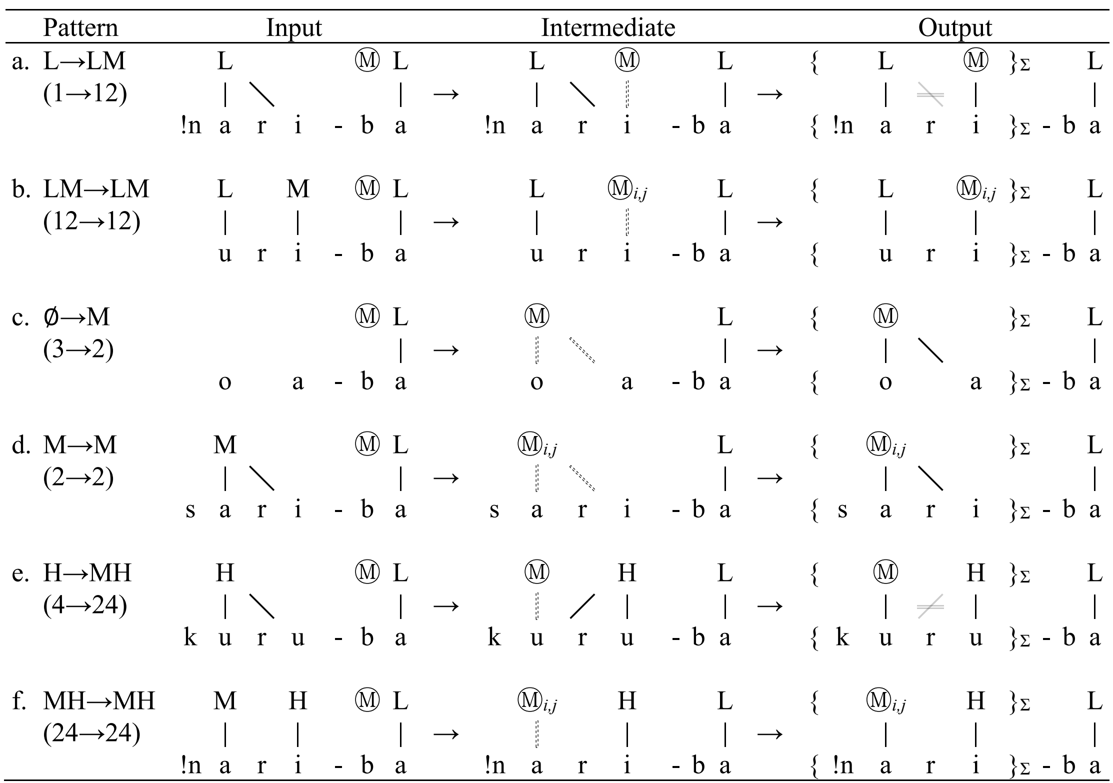

Figure 4: Derivations of weak FF resulting in neutralization

In short, by positing a floating Ⓜ tone we see that the three pairings that are formed and the direction of neutralization between them is anything but arbitrary. In the derivation of weak flip-flop, the floating Ⓜ tone is subject to pre-existing stem-level markedness constraints on contours, in combination with markedness-driven linking, delinking, and coalescence. No flip-flop-specific devices are required. In the next section we show the need for a multi-stage derivation tying the two flip-flop patterns together.

3.3 *Part III: The role of subcategorization* In contrast, strong flip-flop (FF) shows melody exchange without any neutralization. To derive strong FF, we require an additional piece of machinery: PROSODIC

SUBCATEGORIZATION. Like weak FF, triggers of strong FF co-occur with a floating Ⓜ tone but this tone bears a subcategorization frame which requires that it be STEM-EXTERNAL. We represent this as a pre-specified stem boundary which occurs directly before the floating tone, in Figure 5.

Figure 5: Representation of causative reduplication (strong FF trigger) with subcategorizing floating tone

Prosodic subcategorization has a long history of being used to account for exceptional prosodic behavior (Inkelas 1990; Zec 2005; Bennett *et al*. 2018; Tyler 2019; Rolle & Hyman 2019; Kalin & Rolle 2024; *inter alia*). We thus treat strong FF as exceptional, and in turn treat weak FF as the expected outcome of a non-subcategorizing floating tone (i.e. neutralization is expected, exchange is exceptional). This is in line with internal facts of Khoekhoe: weak FF is common and triggered in numerous morphological contexts, while strong FF is much rarer, with causative reduplication the only morphological context where it applies without fail (Brugman 2009:161).

Derivations of strong FF with the six input melodies are in Figure 6, split up into the same two-stage derivation involving an input, an intermediate form, and an output (data comes from Table 5).

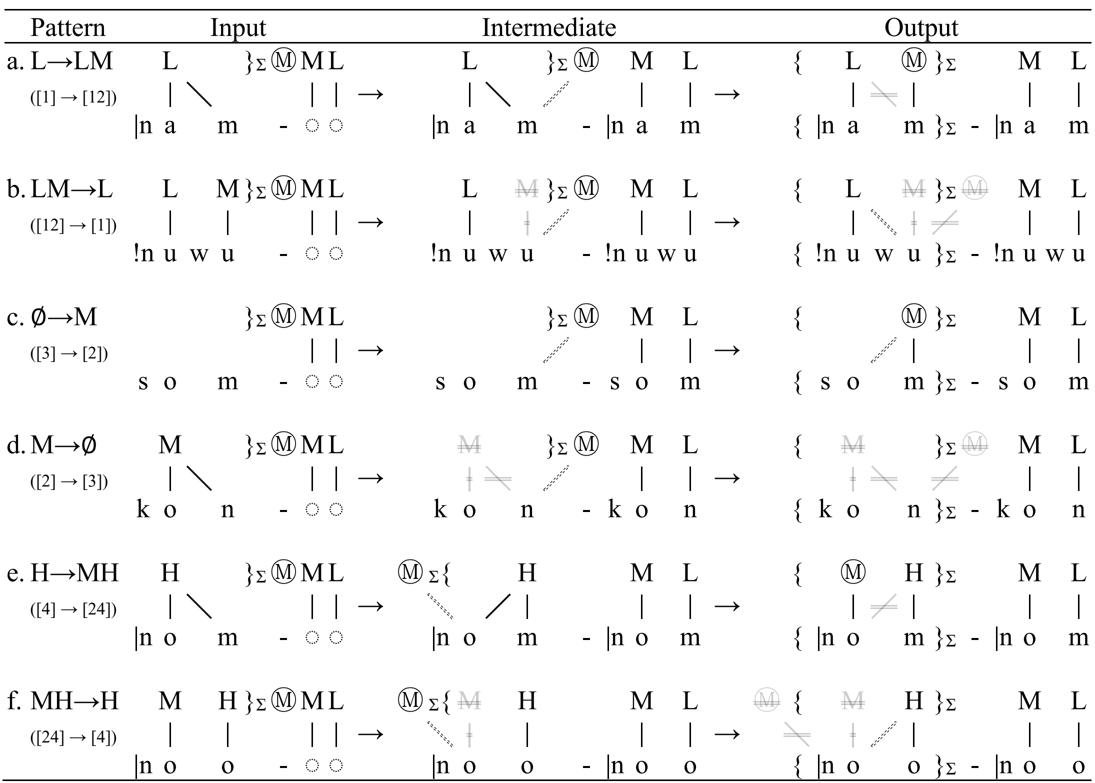

Figure 6: Derivations of strong FF resulting in exchange

As with the weak FF derivations (Figure 4), the floating Ⓜ tone must dock at the intermediate stage (again, the dashed lines). However, because of its subcategorization frame, this floating tone must remain stem-external in each of these derivations. A corollary of this structure is a constraint in the grammar which prevents coalescence over a stem boundary, i.e. the underlying stem-internal M of Figure 6b/6d/6f cannot coalesce with the stem-external floating Ⓜ. This is unlike the comparable weak FF constructions in Figure 4b/4d/4f where there is no pre-specified stem boundary and coalescence takes place between the two mid tones (i.e. $Ⓜ_{i,j}$). Because coalescence is not possible here, instead the stem M delinks when the floating Ⓜ

tone docks (as above, notated in gray and crossed out).[4]

It is at the next stage (Intermediate → Output) where we see tonal exchange take place. At this stage, non-subcategorizing prosodic structure is added (prosodically 'filling out' the word), and further markedness-driven linking and delinking take place. Here, the subcategorization requirements of a morpheme are no longer active. This allows the stem-external Ⓜ of Figure 6a/6c/6e to incorporate into the stem, in order to ensure PROSODIC ALIGNMENT of prosodic boundaries on the tonal tier with the segmental tier. The result is a structure (and surface realization) identical to the counterpart weak FF outputs (Figure 4a/4c/4e).

However, this is not possible with the stem-external Ⓜ of Figure 6b/6d/6f. This is due to an assumption drawn from the earliest iterations of constraint-based modeling (Optimality Theory – Prince & Smolensky 2004): input structure is not literally deleted but rather the delinking operation simply makes it phonetically uninterpretable, a principle known as CONTAINMENT (see also Trommer & Zimmermann 2014 and related works of the Leipzig school). In this figure, although stem-internal M's are delinked they are still phonologically active and prevent the stem-external Ⓜ from incorporating into the stem. The intermediate forms show prosodic misalignment, and because incorporation and coalescence are not options in the output form, the stem-external Ⓜ is 'stranded' in this external position. This violates a constraint in the output that prohibits multiple separate M's associating to moras within the stem (a constraint crucially not affecting the intermediate form), which is resolved by delinking the remaining Ⓜ. This results in the *output* stem structures of Figure 6b/6d/6f appearing comparable to the *input* structures of Figure 4a/4c/4e, hence tonal exchange. Despite this comparableness, as de Lacy 2020 emphasizes, exchange without a dedicated exchange mechanism requires that there can be no point at which the two structures are neutralized in the phonological derivation.[5] This lack of representational neutralization is accomplished in our account by the delinked structure being 'contained' (phonetically uninterpretable but phonologically present).

In total, tonal exchange is the consequence when both coalescence and incorporation are disallowed, demonstrated in the illicit mappings in Figure 7. Also illicit is the mapping in Figure 7c, where a floating tone is linked to a host with a delinked association line directly. We reject such a possible representation, and assume that association must first link with a standard and phonetically-interpretable association line before it can be delinked at a later stage in the derivation (as was done in Figure 6b/6d/6f).

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[4] We leave aside here the OCP violation between the floating Ⓜ tone and its sponsoring suffix with underlying /ML/. One solution is that the Obligatory Contour Principle (OCP – Leben 1973) banning two identical tonemes is sensitive to a lexical/functional division (i.e. sensitive to whether the sponsor is a root or an affix). Another solution is that ML mapping to [21] pitch is actually a phonologically-toneless bimoraic structure, which is mapped to a default pitch when it appears outside of stem position (i.e. instead of /ML/ → [21], it is ∅ → [21]). This ties in nicely with facts about the phrasal tone sandhi system (Table 3), where [21] pitch is a purely derived melody which replaces the 'Intermediate' and 'Bottom' melodies (i.e. toneless ∅ [3] and /L/ [1], respectively). We leave further aspects of this interpretation to future work (especially the behavior of the 'Top' melody /H/ [4]).

[5] The relevant passage from de Lacy (2020:40) is the following (bolding is ours):

> "A general problem with such feature-value switching mappings is how to avoid neutralizing the distinction between the two derivations at any point in the derivation. For example, suppose there is a intervocalic voicing rule that maps /ap+i^{PL}/ to [abi]. A rule is now needed to *devoice* /b/ so that /ab+i^{PL}/→[api]. But how does one now prevent such a devoicing rule from also applying to [abi]? Both /api/ and /abi/ would map to [api], and there would be no apparent exchange (i.e. /ap+i^{PL}/→*voicing* [abi]→*devoicing* [api] cf. /ab+i^{PL}/→*devoicing* [api]).
>
> **Any effective approach must make sure that /ap/ and /ab/ do not neutralize in the derivation**. For example, a chain-shifting lenition process could map /ap+i^{PL}/→[abi] and /ab+i^{PL}/→[ami] (as in Irish eclipsis – Green 2006). A subsequent fortition process could then apply, where nasals become voiceless stops: [am]→[ap]. The result is that underlying /ap/ becomes surface [ab], and underlying /ab/ becomes surface [ap], though via different derivational paths."

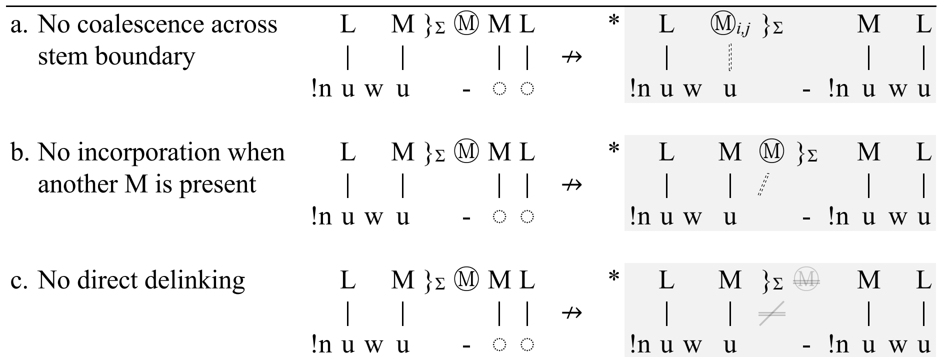

Figure 7: Illicit mappings implicated in tonal exchange analysis

By virtue of the floating Ⓜ linking, it creates new marked structures if another M is present. Their interaction with a grammar prohibiting certain types of outputs (Figure 7) results in *both* being ultimately delinked (at different stages of the derivation). We can term this 'mutual dissimilation' (also referred to as 'mutual annihilation' in Odden 2009).

4 Discussion

The logic of our analysis was as follows: the trigger of tonal exchange sponsors a floating structure which is identical to the exchanging portion (in our case, a floating Ⓜ tone). Under the right conditions (here, the presence of subcategorizing material), the docking of this floating structure causes a kind of dissimilation (in our case, delinking of stem-internal M). Crucially, this dissimilated portion is retained phonologically under the containment thesis (Prince & Smolensky 2004) and may then interact further in the derivation. As such, the delinked portion and the formerly floating portion may further interact in such a way as to condition the delinking of the latter, resulting in their 'mutual dissimilation' if and only if both are present. This analysis necessarily involves a multi-step derivation where certain operations take place first (tone linking and delinking, OCP-triggered dissimilation) and a second set of operations take place later (prosodic incorporation, additional tone delinking).

Thus, we are in agreement with DiCanio *et al*. (2020) – also acknowledged by de Lacy (2020) – that "morphophonological exchange rules cannot be modelled in classical parallelist models of OT" because "the parallelist account cannot generate the correct output forms since it requires an exchange to take place within a single stage" (p. 23). However, this does not warrant a dedicated exchange mechanism, but rather a general architecture that can handle certain kinds of opacity. de Lacy (2020) goes through several possibilities, the one closest to ours being "a two level theory, such as Stratal OT (Bermúdez-Otero 2018)" (p. 40).

Furthermore, tonal exchange – and in fact exchange phenomena as whole – can be understood as a special kind of SUBTRACTIVE MORPHOLOGY. Our analysis of tonal exchange in Khoekhoe as a subcategorizing floating tone fits in with a family of analyses we can call DELETION-AS-ADDITION: despite their surface result, subtractive processes are accomplished by structure addition just as additive processes are (Topintzi 2008:§5; Trommer 2011; Zimmermann 2013, 2017; Trommer & Zimmermann 2014; Yang 2024; *inter alia*). This could be a floating tone as in this study, but also some kind of floating segment, mora, or foot, or some other prosodically deficient structure which results in a marked structure in need of further repair. The deletion-as-addition approach is codified under Bermúdez-Otero's (2012) GENERALIZED NON-LINEAR AFFIXATION (GNLA) theory, characterized as

> "a line of research that seeks to reduce the role of morphology in all instances of apparently nonconcatenative exponence to the insertion of pieces of nonlinear phonological representation whose existence is independently motivated: e.g. floating features or feature-geometric treelets in the case of mutation, fully or partially bare prosodic nodes or prosodic treelets in the case of reduplication and subtraction" (p. 53)

Our account for Khoekhoe tone exchange is one manifestation of the GNLA program.[6]

Regardless of theory, what is important is that none of the mechanics be specific to exchange: in our case, we posited floating tones and prosodic subcategorization, both with a rich history and much cross-linguistic support (see the sections above for many references). Other aspects of our analysis involved markedness-driven linking and delinking (e.g. the OCP), prosodic incorporation and prosodic constituency (e.g. involving the stem), and general architectural assumptions like interpreting delinking not as literal deletion (the containment thesis). All of these analytic devices were developed independently from exchange phenomena, which complies with the stated goal of this paper to derive exchange without a dedicated exchange mechanism.

5 Summary

The starting point of our talk was asking what is a possible (morpho)phonological alternation, or in other words, what is a natural and derivable versus unnatural and perhaps underivable? This formed our background for exploring (morpho)phonological exchange in natural language, whereby [F] → [G] but in this same context [G] → [F]. In a recent paper, de Lacy (2020) sketches two types of analyses. The first assumes a dedicated exchange mechanism to account for these data (such as Transderivational Antifaithfulness constraints or SPE-style [αF]-rules), while the second rejects the need for a dedicated exchange mechanism and derives exchange solely through independently motivated components (whether through representations, the grammar, or their combination).

We have sought to support the second position, and have examined an overlooked type of exchange process: tonal exchange. Our case study came from the Namibian language Khoekhoe, which exhibits a type of ‘flip-flop’ in causative reduplication environments: stems without an underlying mid tone add one (e.g. L → LM) but stems which already contain an underlying mid delete it (e.g. LM → L). We argued that the tonal exchange here was derived *via* a floating mid tone endowed with a prosodic subcategorization frame requiring that it be stem-external, i.e. a representation ‘$\}_{\Sigma}$ Ⓜ’. In the first stage of the derivation, while normally a floating Ⓜ coalesces with a stem M, the prosodic requirement of $\}_{\Sigma}$ Ⓜ prevented coalescence. Instead, this causative Ⓜ triggered delinking of the stem M. Crucially, this stem M is not deleted but only delinked (assuming containment theory – Prince & Smolensky 2004) and remains phonologically active. In a later secondary stage, the delinked M prevents the causative Ⓜ from prosodically incorporating, and the ultimately result was unlinking the causative Ⓜ. We called this ‘mutual dissimilation’.

In total, we characterized tonal exchange as akin to subtractive morphology, and our analysis was in line with deletion-by-addition solutions to this morphological phenomenon. In particular, we supported the ‘Generalized Non-linear Affixation’ program (Bermúdez-Otero 2012; Trommer & Zimmermann 2014), which seeks to reduce all apparent cases of subtractive morphology to additive affixation. Ultimately, we derived tonal exchange by independently required representational devices – floating tones and subcategorization frames – thus showing that exchange can be derived without an additional dedicated exchange mechanism.

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[6] Bermúdez-Otero points to several earlier works as precursors to GNLA, including Lieber (1999:Ch.5), Stonham (1994), Trommer & Zimmermann (2010), among others. Moreover, in later published work Trommer & Zimmermann (2014) adopt an equivalent ‘Generalised Adfixation Hypothesis’ which holds that “morphological operations are restricted to adfixation (prefixation or suffixation) of phonological structure to a (linearly or prosodically) prominent phonological constituent of the base at the same tier” (p. 469).

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