Post nasal neutralization phenomena in Tswana - more on *N… constraints

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1. Introduction

Tswana is a Bantu language spoken in the northern regions of South Africa, as well as in the countries neighboring South Africa to the north (Botswana and Zimbabwe). Through morphological concatenation a nasal and an obstruent can become contiguous in Tswana. This juxtaposition leads to several phonological processes. The nasal is usually deleted in these environments (although it can be parsed into surface structure under duress from high ranking faithfulness and markedness constraints). The obstruent also frequently undergoes featural changes. It is this second process, featural changes in the obstruent as a result of the preceding nasal, that is the focus of this paper. This process is traditionally called “occlusivation” or “hardening” by Tswana grammarians. This occlusivation process is summarized as follows in the standard Tswana reference grammar of Cole (1955):

(1) Occlusivation of obstruents under influence of preceding nasal (Cole 1955:39)[1, 2]

N + b	>	(m)p	N + f	>	(m)p^{h}
N + l, d	>	(n)t	N + r	>	(n)t^{h}
N + s	>	(n)ts^{h}	N + ʃ	>	(ɲ)tʃ^{h}
N + g	>	(ŋ)kg	N + h	>	(ŋ)k^{h}
N + w	>	(ŋ)kw	N + ʔ	>	(ŋ)k

A few explanatory comments are in order. The nasal is placed in parentheses because it is often not parsed into surface structure. However, even when the nasal goes unparsed, it still exerts its featural changing influence on the following obstruent.[3] Cole classifies the *r* of Tswana as voiced (1955:21), however from the table in (1) it is clear that it patterns with voiceless sounds. Krüger and Snyman (s.a.: 81), and Krüger (1998:13) do classify the *r* as a voiceless consonant. I will follow their treatment of the *r* in this paper, and therefore will in the rest of the paper indicate this sound as [r̥]. The glottal stop is not a phoneme in Tswana. The last item in (1) is therefore actually what happens when a nasal is prefixed to a vowel initial stem. The only tautosyllabic consonant cluster tolerated in Tswana is C + w. This is seen in the last item in the column on the left in (1). The appearance of the *k* in this environment seems to be related to the appearance of *k* in vowel initial stems.

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1 The exact same pattern of post-nasal effects is found in Northern Sotho, a very close dialectal variant of Tswana in the broad Sotho-Tswana family (see Poulos & Louwrens 1994:453-7).

2 The same process also occurred historically in intra-morphemic environments in Tswana. However, there is no synchronic variation anymore in this environment (se Creissels 1999:300).

3 The fact that the featural changes occur even when the nasal is deleted, shows that there is a sympathy phenomenon here (McCarthy 2000). The candidate in which the nasal is actually parsed acts as the sympathetic candidate and the post-nasal obstruents of the other candidates are evaluated for their featural faithfulness to the obstruent of this sympathetic candidate. Since I will not deal with the factors that determine when the nasal is parsed in this paper, I will also not comment on this sympathy relation.

The generalization can be stated as follows:

(i) Voiced stops devoice.

(ii) Voiced continuants become stops and devoice.

(iii) Voiceless continuants change to their homorganic aspirated affricates, and if the consonant inventory of Tswana does not have an affricate at that place of articulation, to the homorganic aspirated stop.

(iv) Before the glide *w* and before a vowel, *k* is inserted.

(iv) The absence of voiceless stops from (1) implies that these consonants are unaffected by a preceding nasal.

I will not attempt a full analysis of this phenomenon. I will abstract away from a few of the details in this pattern, namely from the glide and vowel initial roots (*k*-insertion cases), and from the fact that affricates are formed whenever these are available in consonantal inventory. In principle it seems straightforward to account for the fact that affricates are preferred when they are available – in affricates the continuancy of the fricative is preserved, while it is lost in a stop.[4] The analysis presented here should therefore in principle be easily extendable to account for this aspect of the pattern. The insertion of *k* before the glide *w* and before vowel initial stems is more problematic and I will not have anything to say about this.[5] The simplified pattern for which I will offer an analysis here, can then be stated as follows:

(2) Simplified occlusivation pattern analyzed in this paper

a.	Voiced continuant	→	Voiceless stop	/Nv/	→	[mp]
b.	Voiced stop	→	Voiceless stop	/Nb/	→	[mp]
c.	Voiceless continuant	→	Aspirated voiceless stop	/Nf/	→	[mp^h]
d.	Voiceless stop	→	Unchanged	/Np/	→	[mp]
e.	Voiceless aspirated stop	→	Unchanged	/Np^h/	→	[mp^h]

4 This may indicate a need to split IDENT-F into MAX-F and DEP-F, and to distinguish between positive and negative values for features. Changing a fricative into a stop will then incur violations in terms of DEP[-cont] and MAX[+cont]. Changing a fricative into an affricate will, however, only incur a DEP[-cont] violation. The stop instead of affricate will then be forced in the instances where the affricate is absent from the inventory because of some higher ranked markedness constraints that are responsible for determining the inventory.

5 A considerable portion of these roots probably go back to *g*-initial roots in Proto-Bantu (Creissels 1999:308). This does give a historical explanation for the *k*-insertion, although it doesn't help very much with a synchronic analysis. It seems possible to posit an underlying initial *k* for these words, but there is no active process of *k*-deletion word initially that would explain the absence of the *k* when not preceded by a nasal. Cf. acceptable Tswana words like *katse* "cat", *kae* "where", *kolobe* "pig".

(3) Examples from Tswana
(The relevant sounds are underlined.)

a.	/go + N + $\underline{l}$oma/	→	[gon$\underline{t}$oma]	*to bite me*
	INF + 1^{st} OBJ AGR + bite			
b.	/diN + $\underline{b}$aka/	→	[di$\underline{p}$aka]	*occasions, times*
	PL + time			
c.	/go + iN + $\underline{f}$itl^{h}a/	→	[goi$\underline{p}^h$itl^{h}a]	*to hide oneself*
	INF + REFL + hide/			
d.	/N + $\underline{p}$odi/	→	[m$\underline{p}$odi]	*goat*
	SG + goat			
e.	/N + $\underline{t}^h$ipa/	→	[$\underline{t}^h$ipa]	*knife*
	SG + knife			

The Tswana pattern of featural changes under nasal influence is interesting in a context of linguistic universals. The de-frication of continuants is in accord with universal tendencies, but devoicing goes contrary to what normally happens in these environments. The universal tendency to voice post-nasally has lead Pater (1996, 1999) to formulate a universal markedness constraint against nasal + voiceless obstruents clusters (*NC̥) that he motivates on articulatory grounds. Herbert (1986) discusses nasal related phonological phenomena in detail and also comes to the conclusion that universally nasal + voiced obstruent is preferred above nasal + voiceless obstruent. About the Tswana he states that it “is rather unique and remains unexplained” (p. 241). After the initial appearance of Pater’s paper, Hyman (1998) has identified several languages besides Tswana and its direct relations in the Sotho-Tswana family that also avoid nasal + voiced obstruent clusters by either devoicing the nasal or deleting the obstruent. These include Makua, Bubi, Punu (all Bantu languages) and Ulu Muar, Sea Dayak, Mentu Land Dayak (from the Indonesian language family). On the grounds of these data Hyman argues for the existence of the counterpart of Pater's constraint, i.e. for a *ND constraint that militates against a nasal followed by voiced obstruent. He then claims that both of these constraints (*ND and *NC̥) co-exist in the universal constraint set and that it is the relative ranking between them that determines whether a language will devoice or voice post-nasally. Hyman then shows how the ranking *ND >> *NC̥ accounts for the Tswana pattern of postnasal devoicing.

In this paper I will follow Hyman in assuming the existence of a constraint like *ND and I will use this to explain the devoicing exemplified in Tswana.[6] I will also assume with Hyman the existence of phonotactic constraints against the sequence nasal +

6 The constraint that I will assume is somewhat stronger – I will assume a constraint against the sequence nasal + any voiced consonant and not only against nasal + voiced stop. This will allow me to formulate a single constraint against the sequence nasal + continuant, while Hyman needs two separate constraints, one each for the voiced and voiceless continuants. See §2 below.

continuant (*NS and *NZ in Hyman's framework) and against nasal + unaspirated stop *NT, and use this to account for the appearance of non-continuants and aspirates after nasals in Tswana. This is, however, only one half of the story. Whenever markedness constraints exert an influence on the phonology of a language it is always at the expense of faithfulness. Hyman's purpose was not to give a detailed analysis of the Tswana phenomenon, but simply to argue for the existence of *ND. He therefore did not discuss the interaction of *ND with the other markedness constraints, *NS and *NT. And likewise, he also didn't comment on the interaction of these constraints with faithfulness. My purpose in this paper will be to do precisely this, to give a more detailed account of the occlusivation process in Tswana as sketched in (2) above, using Hyman's phonotactic constraints and the markedness and faithfulness constraints with which they interact.

The rest of this paper is structured as follows. In §2 I present a basic analysis of the process with focus on the constraint interactions that get the process going – i.e. markedness over faithfulness. In §3 I will focus on how to constrain the process, i.e. on how to prevent it from over-applying. Here it will be important to determine which faithfulness constraint to promote in the constraint hierarchy. The next section (§4) presents a summary of the constraints and rankings argued for in the first two sections and shows that they predict the correct optimal candidate for all relevant candidates. Finally, in §5 the implications of the proposed analysis is sketched shortly and some ideas for further research are mentioned.

2. Occlusivation after nasals – the triggers

When preceded by a nasal a voiced stop changes into a homorganic voiceless stop. This translates into a ranking with *N[+voi][7] >> IDENT(voi):

(4) Devoicing of voiced stops: *N[+voi] >> IDENT(voi)

/Nb/			*N[+voi]	IDENT(voi)
a.	L	mp		*
b.		mb	*!	

We know that voiced stops are universally more marked than voiceless stops (Kingston, 2000), and therefore we need a markedness constraint against voiced stops, *D.[8] However, we cannot rely on this constraint to trigger the post-nasal devoicing. The ranking IDENT(voi) >> *D is independently needed in the language because voiced stops are not devoiced in environments other than post-nasally.

7 All the phonotactic constraints formulated in this paper apply only to consonants after nasals. *N[+voi] should therefore be read as "no nasal followed by a voiced **consonant**". This crucially does not militate against nasals followed by vowels. The same applies to all other *N… constraints.

8 Where D is shorthand for [+voice, -continuant].

(5) Faithfulness to voicing: IDENT(voi) >> *D (bona *see*)

/bona/	*N[+voi]	IDENT(voi)	*D
a. L bona			*
b. pona		*!	

This, however, does not explain why a voiced continuant changes to a voiceless plosive, rather than to a homorganic voiceless continuant. The answer to this can be found in the fact that voiceless continuants are also not tolerated after a nasal. Padget (1994) offers a possible articulatory explanation for a constraint like this. Co-articulation of adjacent sounds imply that the nasality of the preceding nasal will continue into at least the first part of the following fricative. Nasal fricatives are very rare if not completely unattested in the phonemic inventory of natural languages. This suggests some inherent markedness of such segments. He suggests the articulatory difficulty with such segments is that nasality prefers a completely closed off oral cavity to allow nasal airflow, while fricative require rather strong oral airflow. This is then used by Padget (p. 475-9, 494-9) to explain why fricatives after nasals often either change into stops or into affricates – with affricates only the nasalized portion of the consonant hardens into a stop. We therefore need the constraint *N[+cnt] to outrank IDENT(cnt).

(6) Continuants become stops: *N[+cnt] >> IDENT(cnt)

/Nl/	*N[+cnt]	IDENT(cnt)
a. L nt		*
b. ns	*!	

The last trigger that we have to account for, is the one that is responsible for the aspiration that surfaces on voiceless fricatives. We know already that continuants are not tolerated after nasals and therefore we expect the continuant to surface as a homorganic stop. We still don't have a way of accounting for the fact that aspiration is added to the feature specification of this stop. In order to account for this we have to invoke the phonotactic constraint *N[-asp][9] and rank this higher than IDENT(asp).

(7) Aspiration on voiceless fricatives: *N[-asp] >> IDENT(asp)

/Nf/	*N[+cnt]	*N[-asp]	IDENT(asp)	IDENT(cnt)
a. L mp^h			*	*
b. mp		*!		*
c. mf	*!	*!		

9 Here and throughout this paper [asp] stand for the feature [spread glottis], except when stated otherwise.

We now have all the constraint rankings needed to account for the unfaithful surface forms. It is more difficult to prevent these rankings from causing unneeded faithfulness violations. We have to counter the force of the markedness constraint *N[-asp] in three instances: (i) We have to prevent voiceless stops from aspirating. (ii) We have to prevent voiced stops from aspirating. (iii) We have to prevent voiced continuants from aspirating. The current rankings predict that all marked sequences will neutralize to nasal + aspirated voiceless stop. This is illustrated in tableau (8) below:

(8) Wrong predictions: Over-application of aspiration

			*N[-asp]	*N[+voi]	*N[+cnt]	IDENT(asp)	IDENT(voi)	IDENT(cnt)
/Nl/	a.	; nt	*!				*	*
	b.	L nt^h				*	*	*
/Nb/	c.	; mp	*!				*	
	d.	L mp^h				*	*	
/Nf/	e.	L mp^h				*		*
	f.	mp	*!					*
/Np/	g.	; mp	*!					
	h.	L mp^h				*		
/Nt^h/	i	L nt^h						
	j	nt	*!					

Our current ranking predicts that an aspirated voiceless stop will always win, while this is the desired outcome in only two instances. In the next section I will suggest a way to stop this over application of aspiration.

3. Blocking aspiration

An unfaithful parsing is the result of a markedness constraint outranking a faithfulness constraint. We have seen examples of this in the previous section where the phonotactic constraints that outrank the featural IDENT constraints result in optimal forms that are unfaithful in their specifications for voicing, continuancy and aspiration. But we need to constrain this featural unfaithfulness in some way. Within OT there are two ways to force a faithful parsing at the expense of a markedness violation. This is effected by having either a markedness or a faithfulness constraint outranking the original M >> F pair. If the unfaithful (unmarked in terms of the original M >>F ranking) violates this higher ranked faithfulness or markedness constraint, while the faithful candidate doesn't violate it, the faithful candidate will be optimal even though it violates the original markedness constraint. What we therefore need in tableau (8) above is a constraint violated by candidate (b) but not by (a), and the same or a different constraint violated by (d) but not (c), and the same of a different constraint violated by (h) but not by (g). We will also have to assure that neither of candidates (e) or (i) violates any of these new constraints.

I will argue in §3.1 that there is one constraint that is responsible for preventing the voiceless stops from aspirating (i.e. violated by (h)), and in §3.2 that another constraint keeps the voiced stops and continuants from aspirating (i.e. violated by (b) and (d)). In §3.3 I will consider an alternative approach that treats the two classes of stops (voiced and voiceless) together.

3.1 The voiceless stop

We have to explain why a voiceless fricative aspirates after a nasal, but not a voiceless stop. The problem is that we need *N[-asp] to outrank IDENT[asp] to achieve aspiration on the fricatives. But on the other hand we need IDENT[asp] to outrank *N[-asp] to prevent unaspirated voiceless stops from aspirating. In what follows I propose a solution to this ranking paradox by invoking a special faithfulness constraint that aims at preserving phonemic contrast between aspirated and unaspirated voiceless stops. In this analysis I will develop a proposal from Kirchner (2000) about contrast preservation, although I will not follow him in the details of his analysis.

Kirchner argues that a phonological feature achieves distinctive status (i.e. phonological contrasting status) by virtue of a faithfulness constraint requiring preservation of that feature into surface representation. If such a faithfulness constraint outranks markedness constraints referring to that feature, the feature will have distinctive status. The phoneme inventory of a language is therefore determined by ranking of preservation type faithfulness constraints relative to neutralization (markedness) constraints. Kirchner illustrates this principle with reference to aspiration. He formulates a neutralization constraint that determines the surface distribution of aspiration (ASPIRATE), and a constraint that requires preservation of underlying specification for aspiration (PRES[asp]). In a language where the neutralization constraint outranks the preservation constraint, aspiration will not be contrastive and therefore not distinctive. English is an example of such a language. We know that English aspirates voiceless stops word initially. This pattern is achieved by ranking PRES[asp] below ASPIRATE:

(9) Neutralization of aspiration contrast in English

			ASPIRATE	PRES[asp]
pit	a.	pit	*!	
	b.	L p^hit		*
p^hit	a.	pit	*!	*
	b.	L p^hit		

The reverse ranking will yield a language that preserves underlying contrast in aspiration (like Hindi):

(10) Preservation of aspiration contrast in Hindi

			PRES[asp]	ASPIRATE
pit	a.	L pit		*
	b.	p^hit	*!	
p^hit	a.	pit	*!	*
	b.	L p^hit		

The constraint interactions get more interesting when we consider the fact that very few feature preservations happen in all possible contexts. Even in Hindi (a language whose phonemic inventory even includes voiced aspirated stops), underlying aspiration will not be preserved on a vowel. This means that an input that contained a segment specified as [+syllabic, +aspiration] will be realized on the surface as [+syllabic, -aspiration]. Kirchner offers no direct explanation for this fact. But his analysis of lenition later in his paper (see p. 8-10 especially) can be extended to account for this. He argues that the way in which to achieve context dependent lenition, is to posit context dependent preservation constraints – in the spirit of the positional faithfulness constraints of Beckman (1997). He proposes two types of contextual preservation constraints. The first being positional faithfulness constraints in the classical sense, i.e. constraints like PRES(voice/onset) = preserve voicing in onset position. The second type of contextual preservation constraint that he proposes is preservation of a certain feature when it occurs in combination with a specific specification for *place* of articulation, i.e. PRES(cont/labial) = preserve continuancy of labial segments.

By adding a third type of contextual preservation constraint, we will be able to account for the fact that Tswana aspirates voiceless fricatives, but not voiceless stops, in post-nasal environments. By allowing this third kind of contextual preservation constraint, I will argue that we may also be able capture some wider universal tendencies. The third type that I want to argue must be added to this list, is constraints that require preservation of a certain feature when it co-occurs with a specific *manner* of articulation feature specification. I will below first propose an analysis for the Tswana data, and then show what the possible universal implications of this proposal is.

We need to formulate a constraint that will require preservation of the specification for the feature aspiration only for voiceless stops. Motivation for such a constraint is not far to be found. It is only in voiceless stops in Tswana that aspiration has a distinctive function – that is Tswana distinguishes between phonemes based on their specification for aspiration, but only in voiceless stops. Preserving this specification in voiceless stops will therefore result in preservation of a phonemic contrast. We can formulate this constraint as follows:

(11) PRES(asp/[-voice, -continuant])

Preserve the underlying specification for the feature [aspiration] of a segment that is also [-voice, -continuant].

Ranking this constraint higher than *N[-asp] will block aspiration of unaspirated, voiceless stops.

(12) Blocking of aspiration in voiceless stops: Pres(asp/voiceless stop) >> *N[-asp]

			Pres(asp/voiceless stop)	*N[-asp]
/Np/	a.	☞ mp		*
	b.	mp^h	*!	

This explanation doesn't only result in preservation of underlying specification for aspiration. It also limits the degree of neutralization in post-nasal position and in that sense contributes to contrast preservation. In post-nasal position voiced consonants[10] and unaspirated voiceless stops surface as unaspirated voiceless stops, while voiceless continuants and voiceless aspirated stops surface as voiceless aspirated stops. This means that four classes of phonemes are reduced to two classes with two phonemes to each reduced class. Without the constraint preserving aspiration in voiceless stops, the neutralization would have been three phonemes to one class, and one phoneme to the second class. This would have been a considerable loss in phonemic contrastiveness. The actual Tswana situation is represented schematically below in (13a). What the situation would have been had it not been for the Pres(asp/voiceless stop) is shown in (13b):

(13) Phonemic contrast preservation in post-nasal context in Tswana

a. **Actual Tswana**: with Pres(asp/voiceless stop)

Underlying phonemes	**Neutralized surface form**
voiced consonants voiceless unaspirated stops	voiceless unaspirated stops
voiceless fricatives voiceless aspirated stops	voiceless aspirated stops

[10] In voiced consonants, continuants and stops are distributional allophones (Krüger & Snyman s.a. 80-1; Creissles 1999:315).

b. **Tswana’**: without PRES(asp/voiceless stop)

Underlying phonemes	**Neutralized surface form**
voiced consonants	voiceless unaspirated stops
voiceless unaspirated stops	
voiceless fricatives	voiceless aspirated stops
voiceless aspirated stops	

Appealing to contrast preservation offers a straightforward analysis of why [-aspiration] is preserved on underlyingly unaspirated stops.[11]

3.1.1 Possible universal implications

Kirchner comments (2000: 5) on the fact that some features act distinctively more often than others. He explains this by claiming that some universal ranking holds between the preservation constraints for different features. Preservation constraints for those features that are often distinctive are ranked higher than preservation constraints for those features that are less often distinctive. Kirchner did not extend this line of argumentation to featural combinations, but with a little extra complication this can be achieved. It is known that most languages that make a phonemic distinction based on aspiration, do so only in voiceless stops. A few (like Hindi) also have a phonemic difference for aspiration in voiced stops – and these then usually also have the distinction in voiceless stops. The languages making this distinction on voiced stops, form a subset of those making the distinction in voiceless stops. An even smaller group of languages distinguish aspiration in vowels (cf. the breathy voice vowels of Gujarati). In a search of the UPSID database (containing the phonemic inventories of 451 languages), it was found that 118 languages have voiceless aspirated stops in their inventory as opposed to only 13 that have voiced aspirated stops. The number of languages with breathy vowels was even smaller – only 5. More revealing than the absolute numbers, however, are the patterns of co-occurrence. Below the co-occurrence pattern of voiceless and voiced stops are represented in a table. Both the actual number of co-occurrence and the expected numbers based on the sample

[11] It seems quite possible that an analysis of this phenomenon will be possible within other recent proposals for contrast preservation in OT literature. Within Flemming’s (s.a.) dispersion theory of contrast, we could formulate a constraint that requires preservation of one contrast for aspiration, i.e. MAINTIN 1 ASPIRATION CONSTRAST. Interaction of this constraint with the constraints on minimization of articulatory effort, will then select the voiceless stops to be the class of sounds in which this contrast is maintained. The constraint against effort will probably be something like *[+asp, +voi, -cnt] which will be ranked above the relevant MAINTAIN constraint and *[+asp, -voi, -cnt]. Lubowicz’s (2000) theory of faithfulness as contrast preservation can explain this phenomenon along very similar lines.

of 451 languages are shown. A χ^2-analysis was done on these expected and actual numbers to determine the probability that the patterns observed are coincidental.

(14) Expected and actual patterns of co-occurrence of voiced and voiceless aspirated stops in the 451 languages on the UPSID database

$\chi^2(1) = 23.673, p < .01$

			Voiceless aspirated stops		
			Yes	No	
Voiced aspirated stops	Yes	Actual #	11	2	13
		Expected #	(3)	(10)	
	No	Actual #	107	331	438
		Expected #	(115)	(323)	
			118	333	451

A χ^2-value of 6.635 translates into a $p < .01$. The χ^2-value of 23.673 here, therefore very clearly indicates that the occurrence of voiced aspirated stops depends on the occurrence of voiceless aspirated stops. The results of a similar analysis for the co-occurrence of breathy vowels and aspirated voiced stops, is given in (15) below:

(15) Expected and actual patterns of co-occurrence of voiced aspirated stops and breathy vowels in the 451 languages on the UPSID database

$\chi^2(1) = 5.292, p < .05$

			Breathy vowels		
			Yes	No	
Voiced aspirated stops	Yes	Actual #	1	12	13
		Expected #	(0)	(13)	
	No	Actual #	4	434	438
		Expected #	(5)	(433)	
			5	446	451

Even though the χ^2-value also indicates a significant relationship between the occurrence of these two sets of phonemes, it should be interpreted with more caution. The absolute numbers involved are so much smaller that this can distort the results. The fact that only 1 out of 5 languages with breathy voiced vowels also have voiced aspirated stops, seems to indicate that there is not necessarily a relation between the occurrence of these two sets of phonemes. It does seem, however, that there is a significant relation between the occurrence of aspirated voiceless stops and breathy vowels. This is shown in (16) below:

(16) Expected and actual patterns of co-occurrence of voiceless aspirated stops and breathy vowels in the 451 languages on the UPSID database

$\chi^2(1) = 7.585, p < .01$

			Breathy vowels: Yes	Breathy vowels: No	
Voiceless aspirated stops	Yes	Actual #	4	114	118
		Expected #	1	117	
	No	Actual #	1	332	333
		Expected #	4	329	
			5	446	451

The languages that have voiced aspirated stops and the languages that have breathy vowels, therefore form a subset of the languages that have aspirated voiceless stops. This can be captured if we formulate three different preservation constraints for each of these three classes of segments and rank them in a fixed order. In (17) I order PRES(asp/vowel) below PRES(asp/voiced stop). This ranking is, of course, not as well motivated by the analysis above as ranking both PRES(asp/voiced stop) and PRES(asp/vowel) below PRES(asp/voiceless stop). However, it is still a fact that considerably more languages have voiced aspirated stops than breathy vowels. I try to capture this tendency by the ordering between PRES(asp/voiced stop) and PRES(asp/vowel).

(17) PRES(asp/voiceless stop) >> PRES(asp/voiced stop) >> PRES(asp/vowel)

Markedness constraints that will result in neutralization of underlying aspiration contrast can then be ranked at any place along this fixed ranking, and where it is ranked will determine in which segments the language will preserve the contrast – i.e. with which manner of articulation will aspiration be a distinctive feature. Because of the fixed ranking between these constraints the subset-superset relation discussed above, is captured. If the neutralization constraint is ranked above PRES(asp/voiceless stop), aspiration will not be contrastive in any segments in the language (this is an English type language). With the neutralization constraints ranked between PRES(asp/voiceless stop) and PRES(asp/voiced stop), we get a language that contrasts for aspiration only in voiceless stop phonemes (like Tswana). Neutralization constraints between PRES(asp/voiced stop) and PRES(asp/vowel) result in a language that makes the aspiration distinction in both voiceless and voiced stops (Hindi). Finally, ranking the neutralization constraint below all three of these will result in a language that allows aspiration in voiceless and voiced stops and in vowels.[12]

Kirchner is very careful in his comments on this issue, and he doesn't claim that the ranking between the different preservation constraints is fixed. He claims that there is a "high probability" of this ranking being found in any given language (2000: 5). The same also holds of the constraints and the ranking between them argued for above. This ranking between these constraints will be found in most languages, but this is not a rigidly fixed ranking. There will be languages in which the ranking is different. Kirchner offers no way to incorporate probability in his account and I will also not make any suggestions about this issue here.

3.2 The voiced continuant and stop

The account in §3.1 still does not account for the fact that the voiced continuant and voiced stop don't gain aspiration. If this preservation constraint refers specifically to voiceless stops, then there is no way in which it can block aspiration in segments that are either voiced or continuant or both. The constraint *N[-asp] will therefore force aspiration in both these segments:

(18) Wrong prediction for voiced continuants and voiced stops

			*N[+voi]	*N[+cnt]	*N[-asp]	IDENT(voi)	IDENT(cnt)	IDENT(asp)
/Nl/	a.	L nt^h				*	*	*
	b.	; nt			*!	*	*	
/Nd/	c.	L nt^h				*		*
	d.	; nt			*!	*		

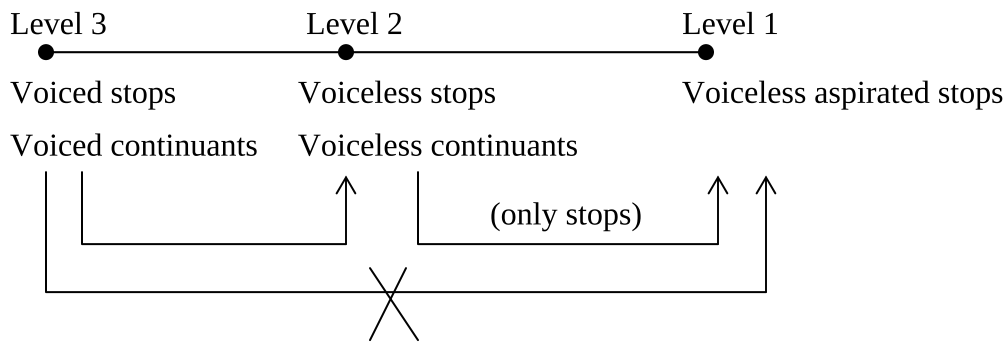
One way to account for the fact that voiced segments do not aspirate, is to define a ternary scale on glottal aperture, and then to require shifts along this scale to be maximally one level. This account basically fits into the theory of ternary scales as developed by Gnanadesikan (1997). I will first present the explanation of the Tswana data below in terms of a ternary scale on glottal aperture, and then I will review how this proposal relates to Gnanadesikan's theory on ternary scales.

We have to define a ternary scale on glottal aperture. At the lowest end of this scale will be segments that are pronounced with the vocal folds tilted away from the midline as far as possible (i.e. segments traditionally considered to be [+spread glottis]). The middle value on the scale will be for segments that are pronounced with the vocal folds tilted away from the midline, but not spread out as far as possible – this roughly corresponds to the voiceless segments in traditional terms. At the highest end of the scale will then be segments pronounced with the vocal folds tilted towards the midline – roughly

[12] Since we have found in the UPSID database that at 4 out the 5 languages with breathy vowels don't have voiced aspirated stops, we will have to allow for the possibility of the neutralization constraints outranking PRES(asp/voiced stops) while being dominated by PRES(asp/vowel).

corresponding to the voiced segments. It is of course possible to voice a segment without closing the glottis – this is why the division between the middle and the high end of the scale cannot be made solely on the grounds of voicing. The scale is stated below with an indication of how the consonantal segments of Tswana will be divided between the three levels. The arrows below the diagram indicate how the occlusivation of post-nasal consonants relate to this scale.[13]

(19) Glottal Aperture Scale (GA)



This makes it clear what will prevent voiced segments from aspirating. Gnanadesikan formulate two relative faithfulness constraints that refer to a scale, namely IDENT-X (which requires an identical value in terms of scale X) and IDENT-ADJACENT-X (which requires a value in terms of scale X that is adjacent to the value of the input). All instances that are violations of IDENT-ADJ-X will therefore also be violations of IDENT-X, but not *vice versa*. This requires the universal ranking IDENT-ADJACENT-X >> IDENT-X. In Tswana we therefore find these two constraints relative to the GA-scale: IDENT-ADJACENT-GA >> IDENT-GA. Any change in the value of a segment for GA will therefore earn a violation in terms of IDENT-GA, but only a change from GA1 to GA3 or *vice versa* will earn a violation in terms of IDENT-ADJACENT-GA. From (19) it is clear that a violation of IDENT-GA is tolerated, but not a violation of IDENT-ADJACENT-GA. This translates into a ranking of IDENT-ADJACENT-GA above both *N[-asp]. In the tableau below it is indicated how this will result in blocking aspiration in voiced segments. This tableau also contains examples of voiceless stops and voiceless fricatives to show that these newly proposed constraints and rankings have no influence on these segments.

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13 It is not clear where aspirated voiced stops would fall on this scale. Schiefer and Kotten (1986) divide voiced aspirate in Hindi into two articulatory parts, namely prevoicing (as with an ordinary voiced stop), and burst + voiceless aspiration (as with an ordinary voiceless aspirate). This implies that the glottis is adducted through much of the oral closure in both ordinary and aspirated voiced stops, but that in the latter, it abducts near the stop release and remains open for a period following the release. This may produce a voiceless aspiration interval or murmur. It therefore seems that voiced aspirated stops might have to fall simultaneously on both ends of the GA scale. The initial part of its articulation (the closure phase) is with a small glottal aperture, while the latter part (after the release) is with a wide glottal opening. The implications of such a cross level division of one sound will have to be determined and it will have to be tested whether the predictions of these implications are actually borne out in natural language.

(20) Blocking of aspiration of voiced consonants: IDENT-ADJACENT-GA >> *N[-asp]

			PRES(asp/voiceless stop)	ID-ADJ-GA	*N[-asp]	ID(cnt)	ID(voi)	ID(asp)
/Nl/	a.	L nt			*	*	*	
	b.	nt^h		*!		*	*	*
/Nb/	c.	L mp			*		*	
	d.	mp^h		*!			*	*
/Nf/	e.	L mp^h				*		*
	f.	mp			*!	*		
/Np/	g.	L mp			*			
	h.	mp^h	*!					*

Crucially IDENT-GA has to be ranked below all three phonotactic constraints proposed here, as all of the changes that are triggered by these constraints earn violations in terms of IDENT-GA. This is indicated in the tableau below where an example is taken from each of the three groups of consonants that are affected by occlusivation.

(21) *N[+cnt], *N[+voi], *N[-asp] >> IDENT-GA

			ID-ADJ-GA	*N[+voi]	*N[+cnt]	PRES	*N[-asp]	ID-GA
/Nl/	a.	nl		*!	*!		*	
	b.	nd		*!			*	
	c.	ns			*!		*	*
	d.	L nt					*	*
	e.	nt^h	*!					*
/Nb/	a.	mv		*!	*!		*	
	b.	mb		*!			*	
	c.	mf			*!		*	*
	d.	L mp					*	*
	e.	mp^h	*!					*
/Nf/	a.	mv		*!	*!		*	*
	b.	mb		*!			*	*
	c.	mf			*!		*	
	d.	mp					*!	
	e.	L mp^h						*

How does this proposal relate to Gnanadesikan's idea of ternary scales? She uses scales to account for two types of phenomena, namely chain shifts and assimilation. She argues that whenever a ternary scale is proposed, it is implied that there can be some language in which this scale is involved in a chain shift, and also that there can be some language in which the scale is involved in attracting assimilation. An example of attracting assimilation within her theory, will be the following (level refers to the value in terms of some scale):

(22) Attracting assimilation

Level 1 + Level 2 → Level 2 + Level 2

Level 1 + Level 3 → Level 2 + Level 3

This means that two adjacent segments want the same value in terms of some scale, but a change of two levels in the scale is not permitted. When two segments at opposite ends of the scale are then adjacent, the one segment will at least move one level so as to be closer to the other. This should be contrasted with a non-attracting assimilation process, which is characterized by the absence of change in the second line in (23):

(23) Non-attracting assimilation

Level 1 + Level 2 → Level 2 + Level 2

Level 1 + Level 3 → Level 1 + Level 3 (no change)

She argues for three such scales, namely on vowel height, inherent voicing and consonantal stricture, and indicates with several detailed analysis how each of these take part in chain shifts and assimilation phenomena. She also considers other possibilities for ternary scales, in particular a scale on sonorant voicing with nasals, liquids and rhotics as the three levels, and a scale on consonantal place of articulation with coronal, dorsal and labial representing the three levels. She rejects both of these because it seems unlikely that any of them will take part in a chain shift and/or an attracting assimilation phenomenon (see Gnanadesikan 1997: 228-230 for duscussion). If we want to argue for a glottal aperture scale within the Gnanadesikan theory of ternary scales, we will have to show that this scale can take part in a chain shift, a non-attracting assimilation process, and in an attracting assimilation process. The analysis of the Tswana data above is an example of a chain shift involving the GA-scale. Attracting and non-attracting assimilation processes in terms of this scale can take the following forms:

(24) Attracting assimilation in terms of GA-Scale

Upwards		Downwards	
t^h + p → t + p	(GA1 → GA2/ __GA2)	p + t^h → p^h + t^h	(GA2 → GA1/ __GA1)
t^h + b → t + b	(GA1 → GA2/ __ GA3)	b + t^h → p + t^h	(GA3 → GA2/ __ GA1)

Non-attracting assimilation in terms of GA-Scale

Upwards		Downwards	
t + b → d + b	(GA2 → GA3/ __ GA3)	p + t^h → p^h + t^h	(GA2 → GA1/ __ GA1)
t^h + b → t^h + b	(GA1→ GA1 / __GA3)	b + t^h → b + t^h	(GA3 → GA3/ __ GA1)

It does seem unlikely that assimilation processes like these will be found easily, but they are not excluded in principle. Assimilation for voicing and spreading of aspiration are both widely attested phenomenon and it is possible that these two may act in concert in some language in the way shown in (24). If some argument can be made to prove that processes like those in (24) can never occur, the argument in favor of the GA-scale will be considerably weaker. However, this will still not exclude the possibility of the existence of such a scale. It is possible that the scales that Gnanadesikan uses are only a special strict subset of the scales active in phonology, and that other scales may not show all the characteristics of the scales that she argues for. She refers to this possibility herself (1997: 228-9) in connection to the two scales that she rejects (the sonorant voicing scale and the consonantal place scale). The GA-scale is at least closer to the scales that Gnanadesikan argues for in that it does take part in a chain shift.

3.3 An alternative: lumping the voiced and voiceless stops together

An explanation that doesn't rely on preservation constraints, but rather uses more standard faithfulness constraints, is also possible. However, this doesn't come for free. The fact that voiceless fricatives gain aspiration but stops (both voiced and voiceless) resist aspiration, can be explained if we assume that stop consonants, but not fricatives, are specified for aspiration. Adding aspiration to the featural representation of a fricative will therefore vacuously satisfy IDENT(asp) – if the fricative is underlyingly not specified for aspiration, adding aspiration to its specification will not change its value for this feature, it will not go from [-aspiration] to [+aspiration]. However, an unaspirated stop consonant will be specified as [-aspiration] underlyingly and aspirating such a stop will result in a violation of IDENT(asp).[14] Claiming that only stop consonants are specified for aspiration (where aspiration is equal to the feature [spread glottis]), are not unproblematic, and I will discuss this problem in more detail below.[15] For the sake of the present discussion, I will assume it to be the case that only stop consonants have a specification for the feature [aspiration]. If we then rank the constraint requiring faithfulness to the specification for aspiration higher than *N[-asp], we can block the aspiration of stops without blocking the aspiration of voiceless fricatives:

14 The inverse will of course also be true. An underlying aspirated stop will be specified as [+aspiration] and de-aspirating it will incur an IDENT(asp) violation. This is not relevant for the Tswana data that we are dealing with here.

15 Similar arguments have been offered with regard to other features. Flemming argues for limiting certain "dimensions" to certain classes of sounds (Flemming s.a.:4). He admittedly uses "dimensions" in a way that is somewhat different from the traditional understanding of what distinctive features are, but the general idea is the same. For instance, he limits specification for formant values to vowels, approximants and nasals, and likewise specifications for noise frequency to sounds that typically contain a significant noise component (fricatives and stops).

(25) Blocking aspiration: IDENT(asp) >> *N[-asp]

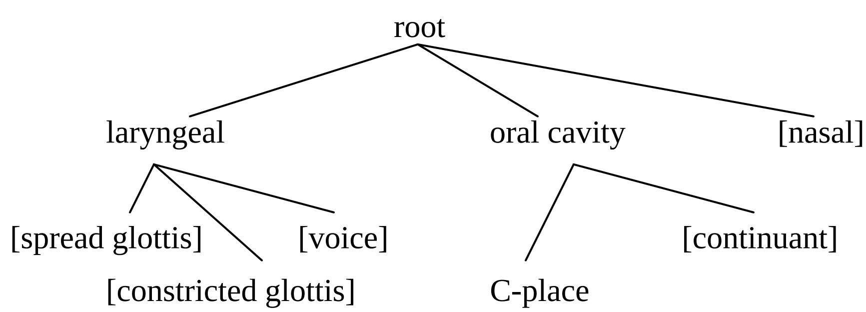
			IDENT(asp)	*N[-asp]	IDENT(cnt)	IDENT(voi)
/Nb/	a.	☞ mp		*		*
	c.	mp^h	*!			*
/Np/	c.	☞ mp		*		
	d.	mp^h	*!			
/Nf/	e.	☞ mp^h			*	
	f.	mp		*!	*	
/Np^h/	g.	☞ mp^h				
	h	mp	*!	*		

I have included the nasal + voiceless fricative to indicate that aspiration with these segments will not be blocked by IDENT(asp) – the /f/ is not specified for [aspiration] and therefore adding [+aspiration] does not violate IDENT(asp) for this input. I have also included a nasal + aspirated sequence here to show that we do get the right prediction also here. With this sequence, the unaspirated candidate would of course have lost even without IDENT(asp).

This does result in a relatively simple way to explain the blocking of aspiration on underlying stops, but this simplicity does not come cheaply. Restricting specification of the feature [aspiration] to stop consonants does not fit into standard assumptions about feature geometry and also does not accord with universal segmental inventories. I will shortly discuss these problems below with some possible defenses against them.

In both Kenstowicz's (1994: 452) and Clements and Hume's (1995: 292) reviews of feature geometry the feature [spread glottis] ([aspiration] in this paper) hangs from the laryngeal node, which in turn is connected to the root node. The feature [continuant], on the other hand, hangs from the oral cavity node, which connects to the root node. There is therefore no direct relation between aspiration and continuancy. This problem is more acute when it is considered that the feature geometric arrangements of these nodes are the same for consonants and vocoids.

(26) Feature geometric relation between aspiration and continuancy in consonants and vocoids



Within this feature arrangement, there is no way to relate [spread glottis] and [continuancy]. They seem to be completely independent of each other. This seems to be supported by universal segmental inventories. Vowels pronounced with a spread glottis have been claimed to exist – the so-called breathy voiced vowels of Gujurati can serve as an example. Likewise the consonant [h] of English is usually considered to be pronounced with a spread glottis, and can therefore serve as an example of an aspirated fricative.

However, even if we accept the classification of breathy voiced vowels as [+spread glottis], the fact this type of vowels is very seldomly attested in the languages of the world, begs for explanation. Likewise it will be necessary to account in some way for the fact that the number of fricatives that are pronounced with a spread glottis are so small compared to stops. Why don't we find a [+spread glottis] version of for instance the fricatives [x, s, f]? If these segments (the breathy voice vowels) are then indeed pronounced with a spread glottis, this pronunciation must at least be universally very marked.

Another possibility is to distinguish between aspiration and spread glottis. An important aspect of the pronunciation of aspirated stops, is the increased intensity of oral airflow after the burst (the puff of air) compared to the unaspirated version. This is indeed the way in which these stops were traditionally described in phonetics texts. Even the 1989 edition of Gimson's standard work on the received pronunciation of British English, uses *inter alia* this description of aspiration – "… an interval of strongly expelled breath" (Gimson 1989: 152). The extreme rapidness of this oral airflow requires a considerable rise in intra-oral air pressure. In order to achieve a high enough level of air pressure in the oral cavity, two conditions must be met: (i) The glottis must be spread to allow a greater quantity of air to flow into the oral cavity. (ii) The oral cavity must be closed off completely. If the oral cavity is closed but the glottis is not spread, the airflow into the oral cavity will not be of the magnitude required to rise oral air pressure to the critical level needed for the intense burst. This will distinguish aspirated and unaspirated stops from each other. If the glottis is spread but there is not a complete oral cavity closure, oral airflow will be continuous and consequently oral air pressure will also not be able rise to the critical level required for the intense burst. In terms of this explanation all sounds will be specified for [spread glottis] – the aspirated stops, breathy voice vowels and [h] will be [+spread glottis]. But only stop consonants will be specified for [aspiration], as they are the only segments in which the requirements for the intense burst can be met. If we understand under aspiration not the spread glottis, but the intense burst that results from a combination of a spread glottis and a complete oral closure, it is possible to restrict the specification of [aspiration] to stop consonants only.

Even if the explanation in the previous paragraph can be accepted, this account for the blocking of aspiration in the continuants is still ridden with problems. It requires a relative serious complication in the theory. An additional feature is added to the set of possible features – we now have in addition to [spread glottis] also [aspiration]. And then this feature has to be restricted so that it is available only to stops. This can be achieved by positing universal undominated markedness constraints ruling out the combination of [aspiration] with all manners of articulation except for stops. But stipulations like these are very costly.

It is therefore possible to keep unaspirated stops from aspirating without relying on contrast preservation constraints. I do not at the present time see any empirical grounds for a choice between the two analyses. It seems that both correctly predict the correct optimal candidates for Tswana. The choice will therefore ultimately have to go to considerations other than empirical adequacy. The theoretical cost of introducing preservation faithfulness constraints seem to be lower than the cost of limiting [spread glottis] specification to stop consonants (or alternatively introducing a new feature on top of [spread glottis]). This is the main reason why I would opt for the contrast option. A wider study of other languages with similar phenomena might shed light on this issue.

4. A summary of the analysis

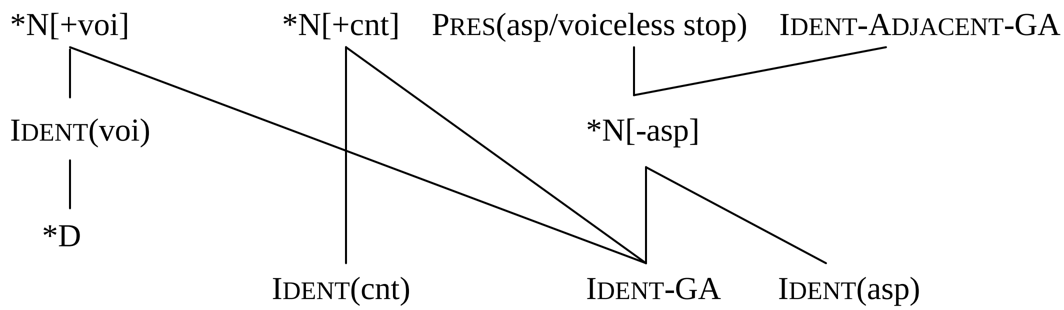
The table below gives an indication of all the constraints and the ranking between them that were argued for in §2 and §3 above. The numbers in parentheses refer to the tableaux in which the rankings were motivated.

(27) Summary of constraints and rankings

Constraints and Ranking	**Motivation**
*N[+voi] >> IDENT(voi)	Post-nasal devoicing (4)
IDENT(voi) >> *D	Occurrence of voiced stops (5)
*N[+cnt] >> IDENT(cnt)	Loss of continuancy after nasal (6)
*N[-asp] >> IDENT(asp)	Aspiration of voiceless fricatives after nasals (7)
PRES(asp/voiceless stop) >> *N[-asp]	Unaspirated voiceless stops resist aspiration (12)
IDENT-ADJACENT-GA >> *N[-asp]	Voiced fricatives don’t aspirate (20)
IDENT-ADJACENT-GA >> IDENT-GA	Universal ranking (Gnanadesikan, 1997)
*N[+cnt], *N[+voi], *N[-asp] >> IDENT-GA	Occlusivation (21)

By way of transitivity these separate rankings can be collapsed into the following partial ordering:

(28) Partial constraint hierarchy for Tswana



It is of course impossible to represent this partial ranking accurately in a tableau and therefore the tableaux below should always be interpreted with (28) in mind. To show that these constraint ranked as in (28) do indeed result in the correct optimal candidate being selected, one input from each of the five relevant consonant classes will be evaluated below with this full constraint set. In these tableaux PRES is shorthand for the constraint PRES(asp/voiceless stop).

(29) Testing the ranking for Tswana

(i) Nasal + voiced continuant

/Nl/	*N[+voi]	*N[+cnt]	PRES	ID-ADJ-GA	ID(cnt)	ID(voi)	*N[-asp]	*D	ID-GA	ID(asp)
a. nl	*!	*!					*			
b. nd	*!				*		*	*		
c. ns		*!				*	*		*	
d. ☞ nt					*	*	*		*	
e. nt^h				*!	*	*			*	*

(ii) Nasal + voiced stop

/Nd/	*N[+voi]	*N[+cnt]	PRES	ID-ADJ-GA	ID(cnt)	ID(voi)	*N[-asp]	*D	ID-GA	ID(asp)
a. nl	*!	*!			*		*			
b. nd	*!						*	*		
c. ns		*!			*	*	*		*	
d. ☞ nt						*	*		*	
e. nt^h				*!		*			*	*

(iii) Nasal + voiceless continuant

	/Nf/	*N[+voi]	*N[+cnt]	PRES	ID-ADJ-GA	ID(cnt)	ID(voi)	*N[-asp]	*D	ID-GA	ID(asp)
a.	mv	*!	*!				*	*		*	
b.	mb	*!				*	*	*	*	*	
c.	mf		*!					*			
d.	mp					*		*!			
e.	☞ mp^h					*				*	*

(iv) Nasal + voiceless stop

	/Np/	*N[+voi]	*N[+cnt]	PRES	ID-ADJ-GA	ID(cnt)	ID(voi)	*N[-asp]	*D	ID-GA	ID(asp)
a.	mv	*!	*!			*	*	*		*	
b.	mb	*!					*	*	*	*	
c.	mf		*!			*		*			
d.	☞ mp							*			
e.	mp^h			*!						*	*

(v) Nasal + voiceless aspirated stop

	/Np^h/	*N[+voi]	*N[+cnt]	PRES	ID-ADJ-GA	ID(cnt)	ID(voi)	*N[-asp]	*D	ID-GA	ID(asp)
a.	mv	*!	*!	*!	*!	*	*	*		*	*
b.	mb	*!		*!	*!		*	*	*	*	*
c.	mf		*!	*!		*		*		*	*
d.	mp			*!				*		*	*
e.	☞ mp^h										

5. Conclusion

From the tableaux in (29) it is clear that the explanation offered here is indeed adequate in the sense that it selects the correct optimal candidate in all five instances. As has been stated earlier (see §3), this explanation is not in any sense unproblematic. It crucially depends on the formulation of contrast preservation constraints, as well as on a ternary scale on glottal aperture. The idea of constraints on contrast preservation is not (yet?) a widely accepted part of OT, and likewise ternary scales have not received a lot of attention. In addition to this, the ternary scale proposed here may not show all of the same characteristics that Gnanadesikan has identified as typical of ternary scales. This situation can be interpreted in two ways. On the one hand it may point to the need of both contrast preservation constraints and ternary scales. On the other hand, it may mean that an alternative explanation for these Tswana data must be formulated that does not rely on either of these devices.

One possibility that seems very plausible and that warrants further investigation, is the idea that voiceless fricatives are specified [+spread glottis], while plan voiceless stops are [-spread glottis].[16] Voiced fricatives and stops will of course be [-spread glottis] – in order to facilitate voicing it is necessary for the vocal folds to be rather close together. Changing the continuancy specification of a voiceless fricative will then automatically result in an aspirated stop. Devoicing a voiced stop will however result in an unaspirated stop (since the voiced stop was [-spread glottis]. Likewise, since voiced the fricative is [-spread glottis], changing its values for voicing and continuancy will not result in an aspirated stop. The gain of this approach is that neither *N[-asp], nor the contrast preservation constraints, nor the ternary scale on glottal aperture is needed. The fact that this explanation seems to be simpler does not guarantee that it is better. Hyman argues for a constraint against the sequence nasal + unaspirated stop on the grounds of some languages in which unaspirated stops aspirate after nasals – he mentions Cewa, Swahili and Pokomo as examples (1998: 24). Herbert (1986: 243-4) also mentions the possibility of aspirating stops after nasals. When the analysis hinted at here is pursued further, these languages will have to be taken into account and the proposals made should also be able to explain the aspiration phenomena in them.

One thing that the analysis in the present paper has shown, is that a single a constraint on what is tolerated in post nasal position (Pater 1996, 1999) is inadequate. There is a rich variety of alternations that happen in post-nasal environment, some of which are contradictory in nature (some languages voice, other devoice, etc.). Even though it therefore seems necessary to assume with Hyman (1998) the existence of conflicting constraints on what is tolerated post-nasally (e.g. both *ND and *NT), what is still missing from this analysis, is an explanation of universal tendencies. Even though some languages do indeed devoice post-nasally, this does seem to be the exception – most languages that have neutralization in this environment voice voiceless stops. By simply formulating conflicting constraints for this environment, the prediction is that both patterns should potentially be equally marked or unmarked, and therefore equally widespread. This is a problem that still needs to be addressed in OT in general – how to account for universal tendencies.

[16] My gratitude to John Kingston who clarified the basics of this possibility to me. Unfortunately, this happened too close to the dead line for submission of this paper and therefore I was not able to pursue this option any further. This is a promising approach and actually warrants a full section in the main body of the paper.

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