Proceedings of the 36th Meeting of the North East Linguistics Society

On the status of voiced stops in Tswana: Against *ND[*]

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1. Introduction

According to Hayes (1999), some phonological constraints are informed by phonetic scales: physically-based hierarchies of phonetic difficulty that predict the articulations that will be phonologically marked. For example, Ohala 1983, Westbury and Keating 1986, and others observe that difficulty of voicing in obstruents is influenced by, among other things, place of articulation, adjacent segments, and phrasal position ("≻" means "is more harmonic than"):

(1) Place of articulation: b≻d≻g
Adjacent segments: post-nasal≻post-obstruent
Phrasal position: phrase-medial≻initial/final

If markedness is grounded in scales of physical difficulty, however, it should not be the case that two markedness constraints should prefer opposite structures, since this would entail that *x* is both more difficult and less difficult than *y*. In this paper, we argue that pairs of freely rankable constraints based on contradictory scales of the kind shown in (2) do not exist.

(2) Non-existent pairs of constraints: C1: x≻y C2: y≻x

Contradictory constraints of this kind put into question the idea that constraints are grounded. They also undermine the typological commitments of Optimality Theory (Prince and Smolensky 1993/2004): if for any markedness constraint that disallows x there is an opposite, freely rankable markedness constraint that favors it, then no

[*]For valuable feedback on this work, we would like to thank Lisa Davidson, John Kingston, John McCarthy, Joe Pater, John Singler, Jennifer Smith, and audiences at Georgetown University, the NYU Phonetics Group, and NELS 36.

typological prediction can be made about the distribution of *x* and *y*. We explore this issue by considering one case where such a pair of constraints has been proposed: *NT and *ND.

The constraint *NT is proposed by Pater (1999) and discussed in the context of phonetic grounding by Hayes (1999). This constraint bans voiceless stops (p, t, k) after nasals (m, n, N), and it has an aerodynamic motivation: when the velum is open, increased airflow through the nasal passages causes increased airflow over the vocal folds, which favors voicing. The upward movement of the velum pulls air through the vocal tract, keeping voicing going into the stop.

(3) *NT: ‘No nasal/voiceless obstruent sequences.’[1]

*NT has various phonological effects, attested in a variety of languages. For example, in Kikuyu, underlyingly voiceless post-nasal stops become voiced after nasals (see (4)). In Mandar, nasals denasalize before voiceless but not before voiced stops (see (5)). In OshiKwanyama, *NT has two different effects: post-nasal voicing in loanwords from English but nasal-stop fusion in native words (see (6)):

(4)	Kikuyu Postnasal Voicing (Clements 1985):		
	/n+koma/	Ngoma	‘I sleep’
(5)	Mandar Denasalization (Mills 1975)		
	/maN+dundu/	mandundu	‘to drink’
	/maN+tunu/	mattunu	‘to burn’
(6)	OshiKwanyama Voicing and Fusion (Steinbergs 1985):		
	‘stamp’	sitamba	
	‘print’	pelenda	
	/e:N+pati/	e:mati	‘ribs’
	/oN+tana/	onana	‘calf’

The presence of *NT in the grammar makes certain typological predictions: (i) some languages should forbid [mp] but not [mb] (Mandar); (ii) if a language allows [mp], it will also allow [mb] (witness contrasts such as camper/amber, enter/ender, and anchor/anger English), and (iii) no language will prefer [mp] to [mb], all other things being equal. It is this last prediction that brings us to Setswana.

2. *ND?

Setswana (Bantu, Botswana) is reported to have post-nasal *de*-voicing. According to several descriptions (see Cole 1985, Hyman 2001, Janson and Tsonope 1991, Kruger and Snyman 1988), underlying word-initial voiced stops devoice after a nasal prefix:

[1] Pater (1999) actually calls the constraint *NC•, but we will follow Hyman’s (2001) usage and call it *NT throughout, to highlight the contrast between this constraint and *ND.

(7) Setswana voiced stops devoice post-nasally:

bata	'look for'	mpata	'... me'
direla	'do smth. for'	ntirela	'... me'
<g>araba[2]	'answer'	Nkaraba	'... me'

Setswana voiceless stops do not change:

p^ha¯a	'slap'	mp^ha¯a	'... me'

As described, this pattern is problematic, because no ranking of faithfulness with the articulatorily grounded constraint *NT and *b will produce devoicing just post-nasally (*/m+bata/→mpata*). Because *bata* maps faithfully, faithfulness to voicing must dominate the general markedness constraint against voiced labials, *b. But the mapping from /mb/ to [mp] violates both contextual markedness (*NT) and faithfulness to voicing, satisfying only the low-ranked *b.

Hyman (2001) proposes that post-nasal devoicing in Tswana is due to a constraint that is the exact opposite of *NT—*ND (see (8)). The analysis of Setswana would then run as follows: faithfulness to voicing must dominate *b, so there is a voicing contrast in the language. *ND dominates faithfulness, however, so the contrast is neutralized in the direction of voicelesness, but only post-nasally.

(8) *ND: "no voiced stops after nasals." (Hyman 2001)

Thus, *ND gets the right result for Setswana, but it seems to make the wrong typological predictions, as pointed out by Odden (2003). Odden observes that fusion to a voiced stop is observed as an effect of *NT (as in OshiKwanyama—see (6)) but not as an effect of *ND. Since there is abundant cross-linguistic evidence for *NT and considerably less for *ND, Hyman (2001) suggests that *ND is normally ranked below *NT, but sometimes the ranking can reverse, as in Setswana. Odden (2003) suggests another conclusion—namely, that we should not judge theories by known typology (and that OT's commitment to factorial typology is wrong-headed).[3]

3. A Closer Look at Setswana

In this section, we take a closer look at the phonology and phonetics of Setswana. We argue that upon closer examination, Setswana does not support *ND.[4]

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[2] The hypothesized underlying voiced velar stop is deleted word-initially in native morpho-phonemic alternations, so /garaba/ maps to [araba]. See more on the status of voiced velar stops in 3.1.

[3] The fusion argument is not necessarily fatal to *ND or to factorial typology. If *ND were indeed a constraint in CON, one would expect to see *some* effects of it—and even if we didn't find a language for every prediction, the gap could be accidental, as Odden suggests. The factorial typology claim is about *possible* languages, not existing languages. Narrowing our focus down to just *ND here, we argue that *ND does not predict even a possible language, let alone an existing one, so it isn't surprising that *ND's other predicted effects are unattested.

[4] Here, we confine ourselves to the discussion of *ND in Setswana, which presents the clearest synchronic case for the constraint. Hyman's additional evidence does not come from synchronic

3.1 Phonetics/history/phonology background

We start with some background on the language. Hyman (2001), Cole (1985), and other sources describe Setswana as contrasting three series of stops: aspirated, ejective, and voiced (see (9)). Note that this inventory, as described, is disharmonic: there are no unmarked, plain stops in an otherwise well-behaved system. As we will show shortly, none of the speakers examined in this study have consonant inventories like this.

(9) Setswana stops, according to existing descriptions

	labial	coronal	dorsal
aspirated	p^h	t^h	k^h
ejective	p’	t’	k’
voiced	b	(d)	

Voiced stops are phonologically marginal in the system. The voiced velar stop never surfaces at all—in loanwords, source [g] is borrowed as ejective [k’] (see (10)). Voiced coronal stops do surface, but only as a reflex of underlying /l/ before high vowels. Underlying /l/ in /bola/ becomes [d] before an /i/-initial suffix, as shown in (11). Similarly, in loanwords, source /li/ is borrowed as [di], as in ‘police,’ which is borrowed as [p’odisi]. Otherwise, /d/ is borrowed as ejective /t’/:

(10) No [g] at all:

“guard”	<u>k’</u>at’i	

(11) [d] is really derived from /l/ through a chain shift

/l/ → [d]/ ___[i]

/bo<u>l</u> + ile/	bo<u>d</u>ile “rotted”	cf. bola
“po<u>l</u>ice”	p’o<u>d</u>isi	

/d/ → [t’] otherwise

/<u>d</u>ur/	<u>t’</u>uru “expensive (Afr)”	

For reasons of space, we concentrate on the one robust contrast involving voiced stops—the three-way contrast among the labials, [p^h/p’/b]. That Setswana should lack a voiced velar stop, [g], is neither surprising nor controversial—dorsal place is the most marked place of articulation for voicing (see (1)). This gap can be straightforwardly explained by undominated ranking of *g. The situation with the coronals is more complicated. The coronal stop that is derived from /l/ also alternates with [t]: (*<u>d</u>irela~<u>nt</u>irela*). In Zsiga et al. in preparation, we present a full analysis of coronals, which is parallel to that of labials but complicated by the chain shift.

Thus, the Setswana inventory as described in the literature is unexpected (a three-way contrast between aspirated, ejective, and voiced stops—all marked laryngeal features), and voiced stops are marginal in the system to begin with. Hyman (2001) brings insight into their marginal status by pointing out that there is a historical explanation. The

alternations. We leave a closer examination of that evidence for future research, although it is possible that similar factors are at work in those cases as in Setswana.

synchronic voiced stops are derived from a series of voiced continuant sonorants /*B, *r, *ƒ/, which are in the process of changing to voiceless stops /p, t, k/. We argue that it should not be surprising to find that this historical change should be more or less advanced for different speakers and different environments.

The environments where consonants can occur in Setswana are quite restricted. There are no clusters and no codas, which is due to high-ranking syllable structure constraints. Therefore, there are only three positions where obstruent consonants can occur: absolute initial position, intervocalic position, and post-nasal position. In the latter case, the nasals are always syllabic—they carry the duration of a full syllable and can bear both tone and stress (Coetzee 2001, Tlale 2005).

(12) Setswana consonants: Absolute initial position (#CV)
Intervocalic (V.CV)
Post-nasal (N`.CV)

Each of these three positions is associated with positional markedness and faithfulness constraints, whose effects are well-attested cross-linguistically. The initial position is subject to positional faithfulness: underlying contrasts (here, laryngeal contrasts) are preserved in this prominent position (see (13)). The intervocalic position favors lenition (see (14)), and post-nasal position favors fortition (see (15)).

(13) IDENT(voice)$_{Initial}$: "Consonants initial in the prosodic word should be faithful to their underlying voicing specifications." (Beckman 1998, Lombardi 1999, McCarthy and Prince 1995)
(14) *VCV: "No stops between vowels." (cf. Kirchner 1998)
(15) *NS: "No continuants after nasals." (cf. Bakovic 1995, Bradley 2001).

There is ample evidence for the activity of these constraints both cross-linguistically and in Setswana. For example, post-nasal fortition applies across the board to [+continuant] sounds, which become [-continuant] after nasals, as shown in (16).

(16) Post-nasal fortition in Setswana

/n+supa/	nts^{h}upa	'point at me'
/n+rata/	nt^{h}ata	'love me'
/n- ɸula/	mp^{h}ula	'shoot me'

We argue that it is the interaction of these independently established constraints that gives rise to what appears to be post-nasal voicing. We turn now to our phonetic data.

4. Phonetics

The data were collected by One Tlale, a native speaker of Setswana, as part of her dissertation research (Tlale 2005). Six speakers of the Sengwato dialect of Setswana were recorded in their home village of Shoshong in north-central Botswana. The data analyzed here are all words spoken in isolation. For each speaker, 6 tokens of each consonant in each environment were obtained. Since the recordings were made in the field, there was some background noise (signal to noise ratio: 30 dB), but all crucial acoustic landmarks were evident.

The acoustic measures we discuss here are the duration of consonantal closure, the duration of the burst (and its presence), voice onset time, or VOT (either negative or positive), and what we term voice perserveration time, or VPT—the voicing "leak" into voiceless closure from a preceding sonorant.

4.1 Aspirated stops: invariant

We found that for all six speakers, aspirated stops were more or less invariant across positions, averaging 80 milliseconds of positive VOT (see (17)).

(17) Aspirated stops

/p^h/	#CV	VCV	NC
Closure		128 ms	94 ms
Burst	11 ms	13 ms	12 ms
VOT	78 ms	79 ms	87 ms
VPT		20 ms	30 ms
allophone	p^h	p^h	p^h

The phonological account of this finding is straightforward: undominated faithfulness to [+spread glottis] for all subjects. There are some important phonetic tendencies to note, however. First, there is significantly longer aspiration following nasals than in other positions, which is consistent with post-nasal fortition. There is also significantly longer voicing perserveration in post-nasal, as opposed to post-vocalic, contexts, showing a tendency toward post-nasal voicing. This is as predicted by *NT, rather than the opposite.

4.2 Voiced and ejective stops: Variation

When we consider the voiced and ejective stops, however, we find a great deal of inter-speaker variation. We find, in fact, that voicing during the closure is not a reliable cue to the contrast between /b/ and /p'/. Rather, this contrast is more accurately described as between *fortis* and *lenis* stops, with varying phonetic implementations for the two series of stops.

With respect to the realization of the voicing contrast, our speakers divide into three groups: three *general devoicers*, one *leniter*, and two *positional devoicers*. We will consider each in turn. Crucially, however, no speaker has a system where voiced stops surface initially and intervocalically but only voiceless stops are allowed post-nasally—the pattern predicted by *ND:

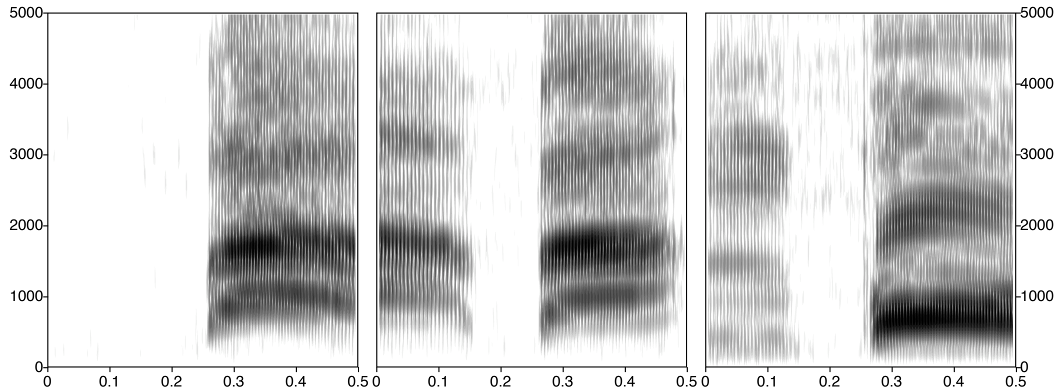
(18) No speaker has this system: [#ba. . .] [. . aba . .] [. . .mpa. . .]

4.2.1 General devoicing

We first turn to our general devoicers. These three younger speakers (a woman and a man in their 30s and a man in his 40s) consistently pronounced voiceless stops in all positions, as can be seen from these spectrograms:

(19) Devoicers

• p̱a • ap̱a •mp̱a



Some average measurements for these speakers are given in (20). The numbers clearly show that the stops are not voiced in any position—VOT is never negative. Bursts are weak and often non-existent, especially in initial and intervocalic position. Note that, once again, there is some evidence of post-nasal fortition, with slight increases in duration, burst, and VOT in post-nasal position. Voice perserveration is also slightly longer in post-nasal position, although stop closure remains almost entirely voiceless. Here, voicing is aerodynamically determined, stopping as soon as the airflow stops, and beginning again as soon as the closure is released.

(20) General devoicing

/b/	#CV	VCV	NC
Closure[5]		90 ms	101 ms
Burst	5 ms	6 ms	8 ms
VOT	5 ms	4 ms	11 ms
VPT		6 ms	11 ms
allophone	[p]	[p]	[p]

There is no evidence of post-nasal devoicing or of *ND. The pattern can be captured by the typical neutralization ranking of markedness over faithfulness: *b dominates

[5] Since the words were recorded in isolation, closure and VPT measurements were not obtained for word-initial stops.

IDENT(voice). It also dominates *NT, so no voicing is allowed to surface in any contexts, including post-nasally (see (21)):

(21) Devoicing: phonology

/bata/	*b	ID(voice)	*NT
bata	*!		
☞ pata		*	
/mbata/	*b	ID(voice)	*NT
mbata	*!		
☞ mpata		*	*

For these speakers, then, we have a process of general devoicing, rather than post-nasal devoicing. The historical change from voiced approximants to voiceless stops is complete for them, and their phonology simply requires the high ranking of a constraint against voiced obstruents.

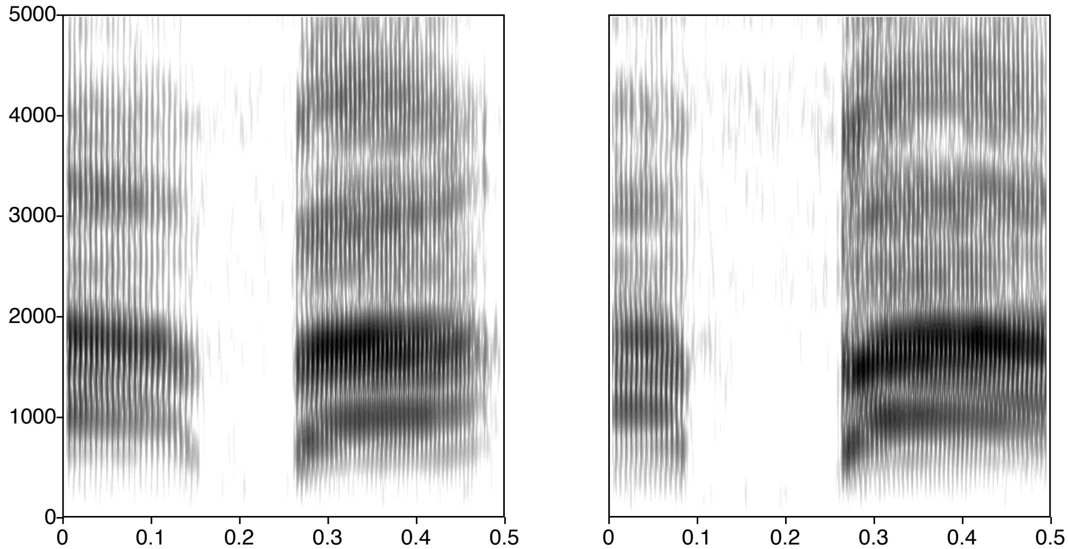
These findings raise the question of whether the contrast between fortis and lenis stops is neutralized in some positions for devoicers. The question is made difficult by the fact that fortis stops are not always clearly ejective, especially the labial ones. They always have a clear, sharp burst and a quick rise in amplitude following release, but there is seldom a definite period of glottal closure following the release. In medial position, the fortis/lenis contrast is clearly maintained mostly closure duration (see (22)), where the fortis stops are on average 50% longer than lenis stops. There is also a small but significant difference in VOT. In initial and post-nasal position, the distinction appears to be neutralized—the authors often could not hear it, including the native speaker of Setswana. We did not conduct any controlled perceptual testing, however.

(22) Comparison of [p] vs [p’] (durations in ms)

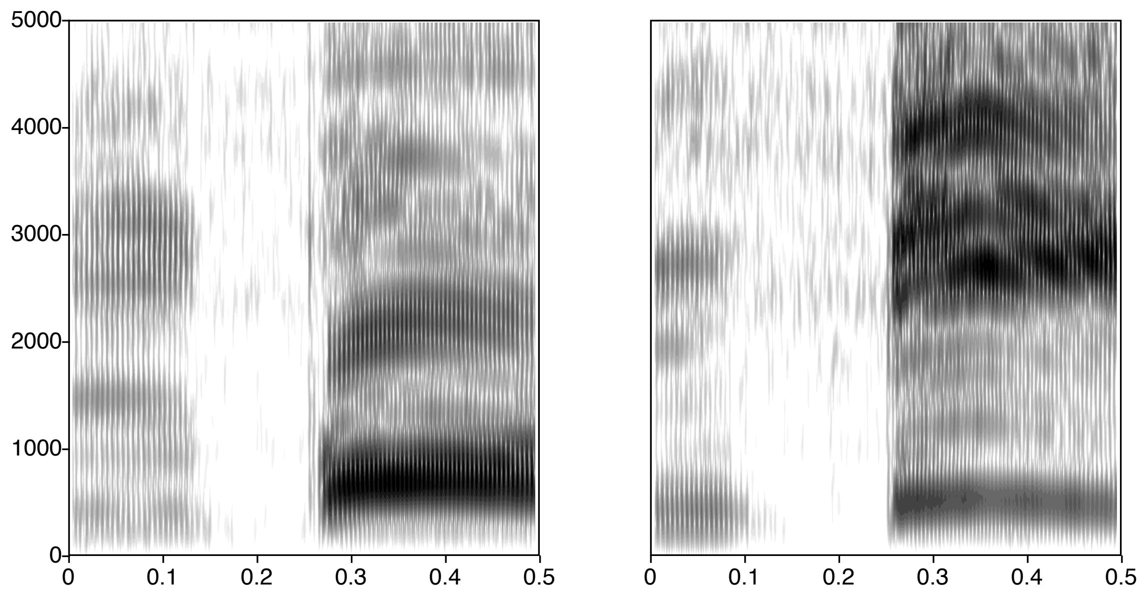
	#CV		VCV		NC	
	[p]	[p’]	[p]	[p’]	[p]	[p’]
Cons. dur.			**90**	**135**	101	111
Burst	5	5	6	7	8	9
VOT	5	9	**4**	**19**	11	13
VPT			6	8	**11**	**21**

(23) Devoicers' spectrograms

[apa] vs. [ap'aa]



[mpona] vs. [mp'exa]



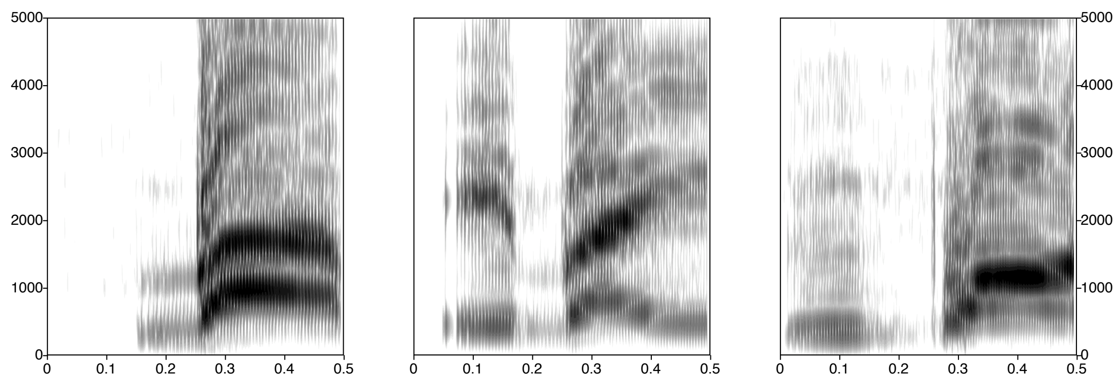
One thing is clear: to the extent that there is neutralization, especially post-nasally, it is a matter of fortition and not devoicing, since these speakers' stops are never voiced in any position.

4.2.2 Lenition

Our group of speakers included one 80-year old woman. She had no devoicing of any sort, and pronounced voiced consonants in all positions. As can be seen from the first two spectrograms in (24), this speaker has not only voicing but also formant structure, which suggests that these are not stops, since there is no closure.[6] (We should note that our other speakers occasionally produced lenited [B] intervocalically, as well, especially in the vicinity of /u/, but lenition is only systematic for this speaker.) Post-nasally, the consonants are voiced and appear to be stops.

(24) Leniter's spectrograms

•βa •eβa • mba



The table in (25) shows the measurements for this speaker. Long negative VOTs indicate voicing throughout the consonant. In intervocalic and initial position, there is no clear release burst, but there is formant structure, which leads us to posit not plosive but approximant allophonic realizations. Again we see the action of post-nasal fortition, however: the approximant hardens to a stop post-nasally, and voicing during the stop closure is somewhat shorter than during the approximant. Even after a nasal, however, the closure is well over 50% voiced.

[6] We interpret the presence of formant structure to mean that these consonants as sonorants, but formant structure is also consistent with these being implosive stops, especially since the vocalic transitions are rather sharp (Demolin 1995; thanks to John Kingston for suggesting this alternative interpretation). Even if this speaker has implosive stops rather than sonorants, though, the pattern provides no evidence of post-nasal devoicing and is consistent with an analysis that ranks faithfulness to voicing high, since this speaker's labials are voiced in all positions.

(25) Lenition

/b/	#CV	VCV	NC
Cons dur.		111 ms	124 ms
% closure		0%	100%
VOT	-123 ms		
VPT		111 ms	91 ms
allophone	[β]	[β]	[b]

This speaker ranks faithfulness to underlying voice high—voicing is found in all positions, including post-nasally. In initial and intervocalic position, however, underlying voiced stops are realized as approximants due to the ranking of *b over IDENT(continuant) and IDENT(sonorant). In post-nasal position, however, the approximant realization is ruled out by *NS, and the consonant surfaces as [b]. Because of high-ranking faithfulness to voice, however, devoicing to [mpata] is ruled out.[7]

(26) Lenition: Phonology

/bata/	IDENT(voice)	*NS	*b	IDENT(cont)	*NT
bata			*!		
pata	*!				
☞ Bata				*	
/mbata/					
☞mbata			*		
mpata	*!				*
mBata		*!		*	

In summary, this 80-year-old speaker retains the historical pronunciations. For her, the sound change of approximants to stops has not really begun. She does show post-nasal hardening, but not post-nasal devoicing. Again, there is no evidence of *ND, but there is evidence of high ranking of IDENT(voice) and *NS.

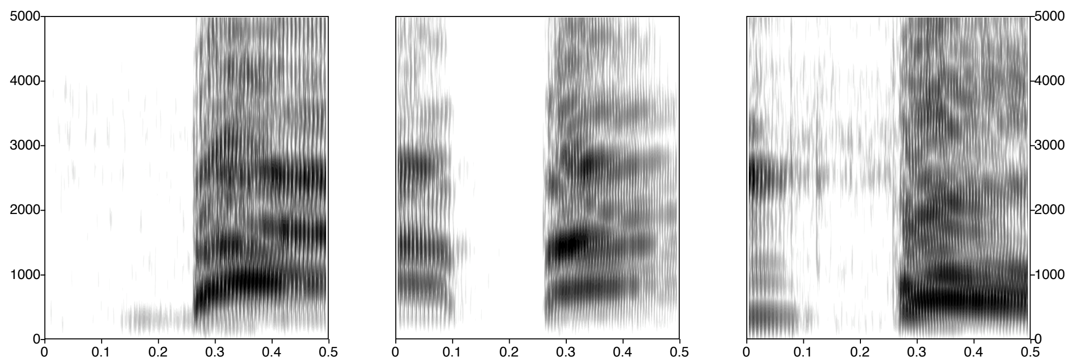
4.3 Positional devoicing

The last two speakers are a man in his 80s and a woman in her 40s. We term these speakers *positional devoicers*, since they produced voiced stops in initial position but voiceless stops intervocalically and post-nasally.

[7] Under Richness of the Base, this analysis predicts that this speaker should have a voiced-voiceless contrast between voiced approximants and plain unaspirated stops word-initially and intervocalically. It is possible that plain stops and fortis (ejective) stops merge for this speaker—recall that fortis stops are often not clearly ejective.

(27) Positional devoicers

•ba • apa • mpa



These speakers have a large negative VOT in initial position, and a slight positive VOT in non-initial position. For these speakers, we transcribe initial stops rather than approximants, because bursts were generally evident (though weak) and there was no formant structure during the closure. Speaker 3 shows a tendency towards intervocalic lenition—her stop closures are significantly shorter in this position.

(28) Positional devoicing

/b/	#CV	VCV	NC
VOT	-103 ms	+2 ms	+7 ms
Burst	3 ms	3 ms	8 ms
Closure		169 ms (S5) 89 ms (S3)	157 ms
VPT		57 ms	32 ms
allophone	[b]	[p]	[p]

Of the positions in which consonants can occur in Setswana, word-initial position is aerodynamically the hardest for voicing (Hayes 1999, Ohala 1983, 1999, Westbury and Keating 1986). This suggests that the presence of voicing initially is due not to markedness but to faithfulness. Thus, we posit high-ranking of a positional faithfulness constraint, which preserves the voiced stop in initial position, IDENT(voice)$_{initial}$. This constraint dominates *b, allowing voicing word-initially. Since *b dominates *NT, voiced stops devoice post-nasally:

(29) Positional devoicing: phonology

/bata/	IDENT(voice)$_{initial}$	*b	IDENT(voice)	*NT
☞ bata		*		
pata	*!		*	
/mbata/				
mbata		*!		
☞ mpata			*	*

If only initial and post-nasal position are considered, this pattern looks like post-nasal devoicing; however, devoicing intervocalically indicates that it is initial and not post-nasal position that is set apart for special consideration in the phonology. Under this positional neutralization ranking, devoicing applies everywhere but word-initially (see (30))—and, since Setswana only has consonants in two other positions, intervocalic position presents the crucial evidence.

(30) Intervocalic and not just post-nasal devoicing

/aba/	IDENT(voice)$_{initial}$	*b	IDENT(voice)	*NT
aba		*!		
☞ apa			*	*

With the exception of the positional faithfulness constraint, the rankings of positional devoicers are identical to the rankings of the general devoicers (see (21))—voicing neutralizes due to *b dominating IDENT(voice) and *NT. This is devoicing in non-initial, not post-nasal contexts.

It would appear that for these speakers, the sound change from voiced approximant to voiceless stop is delayed in the prominent initial position—indicating high ranking of positional faithfulness.

The following table summarizes our phonetic findings. Crucially we found no evidence of the pattern predicted by *ND: voiced stops in all positions except post-nasally. The attested patterns are all predicted by slightly different ranking of phonetically-grounded and cross-linguistically attested constraints.

(31) *ND not found

/b/	#CV	VCV	NC
Devoicers:	p	p	p
Leniter:	β	β	b
Positional:	b	p	p
Not found:	**b**	**b**	**p**

5. Summary and discussion

Our phonetic study of stops in Setswana found no evidence of post-nasal devoicing. Describing Setswana as having post-nasal devoicing is not consistent with the facts of the language, since no speakers devoice *just* post-nasally. The patterns we found in Setswana point to a marginal status of voiced stops in the language; there is a general aversion to them that results in devoicing for some speakers and in lenition for others. The historical change from approximants to stops is delayed in word-initial position for some speakers because of positional faithfulness. The pattern is further complicated by post-nasal fortition—a pervasive process in Setswana that prohibits all continuants, not just approximants, post-nasally. The combination of these three factors (aversion to voiced stops, positional faithfulness, and post-nasal fortition) results in the pattern that appears to look like post-nasal devoicing, but this interpretation does not hold up when the system is examined closer.

A broader theoretical issue here is the status of freely rankable constraints that are based on contradictory phonetic scales. If, as we claim, constraints cannot directly contradict each other, then what grammatical principle defines possible phonetic scales? Specifically, can some scales reflect articulatory considerations and others—perceptual ones, and can such constraints contradict each other?[8] This last question is especially relevant to the discussion of *NT and *ND, since Hyman (2001) suggests that *ND might have a perceptual motivation along the lines of Ohala (1993): since nasal-voiced stop sequences sound similar to singleton nasals, devoicing just post-nasally avoids this neutralization for the benefit of the hearer even though it requires an output that is more marked from an articulatory point of view.

We would argue that scales are never *contradictory*, but they are often *orthogonal* (Hayes 1999 makes a similar point). For example, nasalized vowels are perceptually marked—nasality distorts formant structure, so nasalized vowels are poor bearers of perceptual contrast. A scale to that effect states that oral vowels are more harmonic than nasal vowels (see McCarthy and Prince 1995). On the other hand, nasal vowels are the preferred vowels in the vicinity of nasal consonants for articulatory reasons (assimilation)—so the relevant scale will state that *nasal* vowels are actually more harmonic than oral ones in the context of nasal consonants. These two scales are *orthogonal*, since they deal with matters of general vs. contextual markedness, but they are not *contradictory*, since they do not rank the same two structures in opposite order:

(32) *Vowel nasality scale*: $V_{oral} \succ V_{nas}$

(33) *Nasalization scale*: $V_{nas}N \succ V_{oral}N$

The post-nasal voicing scale, which is the basis for *NT, does not have a contradictory counterpart, but there are several fairly uncontroversial scales that are orthogonal to it—for example, the obstruent voicing scale, according to which voiceless stops are more harmonic than voiced ones, and the scale that is the basis of the fortition constraint, *NS. The details of individual scales must ultimately be worked out on a constraint-by-constraint basis, with careful attention to typology.

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[8] A far-from-exhaustive list of Optimality-Theoretic work on this subject includes Boersma 1998, Crosswhite 1999, Jun 1995, Prince and Smolensky 1993/2004, Smith 2002.

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Zsiga, Elizabeth, Gouskova, Maria, and Tlale, One. in preparation. (pick some title).

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