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A comparative study of depression in Bantu, Khoisan and Chinese Wu – laryngeal settings and feature specifications

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Abstract
This paper aims to provide an overview of our current understanding of depressors by offering a comparative perspective of the types of depressors from Bantu, Khoisan and Chinese Wu. Depressor effects in Bantu/Khoisan, on the one hand, and Chinese, on the other, are hardly dealt with together leaving a more holistic approach untapped. This paper begins to bridge that gap by bringing together current findings to establish the full scope of depressor effects, from which future analyses can then build on. It is systematically observed that depressors in these languages are not restricted to voicing only. Rather, they range from voiced and breathy sounds – the most unmarked – to voiceless unaspirated sounds and even voiceless aspirated sounds as the most marked depressor type. The expansion of depressors to voiceless aspirated sounds is particularly interesting, since these sounds are traditionally assumed to correlate with a high pitch which is characteristic of high tone. Thus, the laryngeal configurations for voiceless depressors are examined and compared between Bantu, Khoisan and Chinese Wu. Proposed feature analyses for depressors are also discussed and compared.

Keywords: depressors, Bantu, Khoisan, Chinese Wu, laryngeal specification

1. Introduction

Depression refers to the phenomenon where some consonants exert a tone lowering effect on following vowels. Such consonants are thus referred to as depressor consonants. Another common effect of depressor consonants is that they act as a tone blocker in High Tone Spreading. According to Rycroft (1980:1), the correlation between consonants and low tone was first formally reported in Beach (1924), where Beach found that in isiXhosa, "all consonantal initials of syllables may be divided into two classes according to their tonetic

relationships… the high class and the low class". The "low class" in isiXhosa involves voiced aspirants and voiced stops, which could lower tones on their following vowels. This phenomenon was also later found in isiZulu (Doke 1926). This finding echoes perfectly the studies on Chinese tones where Middle Chinese tones were divided into upper register and lower register according to the voicing of the initials. The term "depressor" was officially used more consistently since Lanham (1958), who describes a group of isiXhosa consonants as triggering "… a lowering effect on all except 'low level tones'" (Lanham 1958:66)[1].

Although depressors are traditionally assumed to be voiced, studies on Bantu, Khoisan and Chinese Wu indicate that depressors go far beyond this single consonant type.[2] This paper aims to provide a cross-linguistic overview of depression in terms of depressor types, laryngeal configurations, and feature specifications for depressors, based on data already reported in the literature. Our goal is to use this synthesis to draw broader generalisations that can then feed into detailed analyses. The organisation of the paper is as follows: section 2 introduces two major categories of depressors, viz. unmarked and marked, from a selection of five languages in Bantu (Xitsonga, Ikalanga, isiZulu, isiXhosa, siSwati), one language from Khoisan (Tsua) and one language from Chinese Wu (Shanghainese). Each category is further found to include two types of depressors, which we will discuss in detail. Of particular interest is the laryngeal status of the marked depressors, which are normally associated with a high rather than a low tone. The laryngeal settings for voiceless unaspirated depressors will be compared and summarised in section 3. Section 4 reviews two classic laryngeal feature proposals before looking at alternative feature assignments for depressors, and section 5 offers some concluding remarks.

2. Depressor types and languages

This section reviews depressors from seven languages, namely Xitsonga, Ikalanga, isiZulu, isiXhosa, siSwati from the Nguni branch of Bantu, Tsua from Khoisan, and Shanghainese from Chinese Wu. Data are drawn from sources as cited below. We categorise depressors in these languages into unmarked and marked, where unmarked refers to those consonants which are canonically understood and seen to act as depressors in almost all languages that have depressor effects, and marked for the less common cases, which in fact do occur in addition to the unmarked types. The unmarked category includes truly voiced and breathy depressors. The marked depressors consist of voiceless unaspirated and aspirated depressors. The following subsections discuss each of the four types of depressors in detail.

2.1. Unmarked depressors

The most common unmarked depressor is voicing, followed to a lesser extent by breathy sounds. Voiced stops, fricatives, affricates, clicks and their labialised or palatalised variants are recorded as depressors in all seven languages. (1) lists the voiced depressors of the seven languages. Data are drawn from the following sources: Mathanwange (1999) for Ikalanga; McLaren (1944) and

[1] However, as Rycroft (1980) points out, the earliest researcher that ever used the expression "depressed" was the bishop Colenso (1871:9), who found that "some words, though spelt alike, are distinguished in utterance by the voice being depressed on a certain syllable…Ex. beka, 'put down'; béka, 'look' ". But it remains unclear whether his use of the term is for "consonantally conditioned lowering of pitch" or just for low tone (Rycroft 1980:2).

[2] Chinese Wu is a branch within contemporary Chinese which Chao (1928) describes as a group of dialects extending over the South-eastern part of the province of Jiangsu and the North-eastern half of the province of Zhejiang. Taihu Wu is a sub-branch of Chinese Wu to which Shanghainese Wu belongs.

Lanham (1958) for isiXhosa; Rycroft (1976) and Lanham (1960) for SiSwati; Doke (1926), Lanham (1960), Rycroft & Ngcobo (1979) and Khumalo (1981) for isiZulu; Baumbach (1987) and Lee (2009) for Xitsonga; Mathes (2015) for Tsua and Zhu (2006) for Shanghainese.

(1) Unmarked depressors: voicing[3]

Ikalanga	**Xitsonga**	**Tsua**
b, b͡g, b͡z, d, d̪, d͡z, d͡ʒ, d͡ʒʷ, gʷ, v, z, zʷ, ʒ	b, d, dl, g, bv, dɮ, dz, dʒ	b, d, dz, ɻ, g, ɢ, g|, g‡, g‖, |ɢ, ‖ɢ

In languages that contain breathy sounds, it is found that non-depressors, such as nasals in isiXhosa, become depressors once they gain the breathy quality. Hence, for example, plain nasals [n] and [m] are non-depressors whereas their breathy counterparts [n̤] and [m̤] are depressors. Ikalanga, isiXhosa, isiZulu and Xitsonga in (2) are said to have breathy depressors.

(2) Unmarked depressors: breathiness (DEP=depressors)

nonDEP/DEP	**Ikalanga**	**isiXhosa/isiZulu**	**Xitsonga**	**Shanghainese**
nonDEP		m, n, ɲ, ŋ, w, j, l, (r)[4]	m, n, ŋ, l, r, w, j	m, n, ŋ j, w, l
DEP	ɦ	m̤, n̤, ɲ̤, ŋ̤, w̤, j̤, l̤, (r̤)	ᵐb̤, ⁿd̤, ᵑg̤, v̤, m̤, n̤, ŋ̤, bv̤, dz̤, dʒ̤, ɦ, l̤, r̤, w̤, j̤	m̤, n̤, ŋ̤, w̤, j̤, l̤,

2.2. Marked depressors – voiceless aspirated depressors

2.2.1 Xitsonga

In Xitsonga, the voiceless aspirated depressors are /pʰ tʰ kʰ pfʰ tsʰ tʃʰ tlʰ/ (data from Baumbach 1987; Lee 2009). There is a process of High Tone Spreading (hereafter HTS) that spreads a prefix High tone to its following bi-syllabic root except the final syllable. Thus in (3a) the High tone on the prefix /i-/ (marked by an acute accent) spreads to the first syllable /ri/ of the root. By contrast this HTS is blocked in (3b) when the root-initial consonant is a voiceless aspirated depressor.[5]

[3] Ikalanga, Xitsonga, and Tsua are reported to have fully voiced depressors. Although voiced obstruents are also recorded in isiZulu, siSwati, isiXhosa, and Shanghainese, they are found to be phonetically voiceless in most studies and are thus classified as 'voiceless depressors' and not presented here.

[4] isiXhosa has the plain vs. breathy /r/ contrast. /r/ in IsiZulu occurs only in words of foreign origin (Rycroft & Ngcobo 1979; Ziervogel 1967).

[5] Data in (3a&b) are from Lee (2009). However, in his recent work, Lee (2015) shows that the HTS blocking requires *both* an initial depressor and a H tone in the root. Thus examples in (3c) with a depressor but no H tone in the root show no HTS blocking. Despite this complexity, we can see that depressors play a role in HTS blocking in Xitsonga.

(3) Xitsonga depressors and HTS [Data source: Baumbach (1987:53-56) and Lee (2009:35-36)]

a.	**nonDEPs**	**Root**	**Prefix+Root**		**Gloss**
	r	rìbyè	í ríbyè		"it is a stone"
	p	púlá^{ŋ}gi	í ˡpúlá^{ŋ}gì		"it is a plank"
	l	léró	ɦí ˡléró		"it is that one"
b.	**DEPs**	**Root**	**Prefix+Root**		**Gloss**
	ts^{h}	ts^{h}ùrí	í ts^{h}ùrí	*í ts^{h}ûrí	"it is a mortar"
	tl^{h}	ntl^{h}àmú	í ntl^{h}àmú	*í ntl^{h}âmú	"it is a trap"
	tʃ^{ɦ}	tʃ^{ɦ}ìpá	í tʃ^{ɦ}ìpá	*í tʃ^{ɦ}îpá	"it is a pensioner"
	t^{h}	t^{h}ònsí	í t^{h}ònsí	*í t^{h}ônsí	"it is a drop"
	k^{h}	k^{h}òswá	í k^{h}òswá	*í k^{h}ôswá	"it is a half portion"
c.	**DEPs**	**Root**	**Prefix+Root**		**Gloss**
	b	baku	í báku		"cave"
	r̠	r̠ole	í r̠óle		"calf"

2.2.2 Ikalanga

A second language that has voiceless aspirates as depressors is Ikalanga, spoken in Botswana. Mathangwane (1999:196) distinguishes three types of voiceless aspirates in Ikalanga – regular aspirates /p^{h}, t^{h}, k^{h}/, labialised aspirates /pk^{wh}, k^{wh}/ (historically derived from velarisation), and a special set of "breathy aspirates" /p^{ɦ}, t^{ɦ}/. The first two types are regular voiceless aspirates that are non-depressors. Of particular interest is the "breathy aspirate", which is a term Mathangwane created only for the purpose of easy identification. These aspirates were later transcribed as /P^{h}, T^{h}/ in Downing (2009), who argues that although Mathangwane uses the term "breathy aspirates", these aspirates are in fact "neither voiced nor breathy voiced". Both Mathangwane (1999) and Downing (2009) recognise two types of contrasting voiceless aspirates – non-depressor and depressor aspirates. The "breathy aspirates" such as /P^{h}, T^{h}/ have a depressor effect while normal voiceless aspirates do not. In this paper, we adopt Downing's (2009) transcription for "breathy aspirates" (in capital letters). Examples of "breathy aspirates" and normal voiceless aspirates are given below.

(4) HTS and blocking in Ikalanga (Mathangwane 1998:115)

a. Normal aspirates: non-depressors
ku-ʃímá p^{h}ilé → ku-ʃímá p^{h}ílé "to hate a bad singer"
b. "breathy aspirates": depressors
ku-ʃímá P^{h}ilé → ku-ʃímá P^{h}ilé "to hate a steenbuck"

Mathangwane (1999) acoustically shows that "breathy aspirates" are dramatically distinct from non-depressor aspirates in that "breathy aspirates" have a longer VOT duration (54 vs. 66ms),

a longer duration of noise in the high frequencies (the noise duration in higher frequencies is 32msec longer for "breathy aspirates"), and a consistently lower pitch value (195 vs. 248 Hz).[6]

2.2.3 Tsua

A third language is Tsua, a Kalahari Khoe East language of Central Khoisan, spoken mainly in Eastern Botswana. Being a Khoisan language, Tsua is distinctive from Bantu in having a large inventory of click sounds as depressors. In Tsua the aspirated depressors are /p^h, t^h, ts^h, c^h, k^h, q^h, $ǀ^h$, $ǂ^h$, $ǁ^h$, $ǀq^h$, $ǂq^h$, $ǁq^h$, h/, according to Mathes (2015:34, 39). In terms of tonal inventory Tsua also differs from Bantu in having a wider range of tones with six bimoraic tones: H-level, HM-falling, HL-falling, Mid-double-rise (M level), MH-rising and ML-falling. In addition, there are two extra depressor-induced tones called DH-L (Depressed High Low) and DH-M (Depressed High Mid). The tones that are depressed are marked by a subscript symbol "+" beneath the vowels. Examples of DH-L and DH-M words are listed in (5), drawn from Mathes (2015).

(5) DH-L and DH-M words in Tsua (Mathes 2015:112-113)

DH-L		DH-M	
gǫ̀ò	"aardvark"	k^hą́ē	"to stab"
gǀą́à	"Silver tree"	ts^hą́ā	"water"
ts^hǫ́è	"person"	gǫ́ā tsúrī	"much later"
ɻǫ́à	"ash"	gǀą́ā	"to put in smoothly"

Although rare, depressor aspirates are not unique to Bantu and Khoisan, but are also observed in Sino-Tibetan languages like the Wujiang dialect of Chinese Wu and Mon-Khmer Bolyu (Edmondson & Gregerson 1996).

2.2.4 Wujiang

Wujiang is a sub-dialect of Chinese Wu[7], spoken in the Wujiang county, south of Suzhou. The Wujiang dialect preserves the four tones from Middle Chinese but further splits into upper register (Yin) and lower register (Yang), thus giving rise to as many as eight tones. As in other Wu dialects, the high tone register has an affinity with voiceless initials while the low tone register associates with voiced consonants. However, the Wujiang dialect differs from other Wu dialects in one aspect, namely that its voiceless aspirates have distinctively lower tones than voiceless unaspirated obstruents. Therefore, in some analyses, a third "aspirated tone" level is proposed to distinguish tones induced by voiceless aspirated and unaspirated consonants. The three-level tonal analysis is given below in (6) from Shen (1994:279).

[6] Mathangwane's (1999) data are not subjected to statistical analysis. This would be useful to establish whether the stated numeral differences between "breathy aspirates" and regular aspirates are significant.
[7] Both Wujiang and Shanghainese are dialects of Chinese Wu spoken in the south-eastern coastal area of China.

(6) Three tone registers of Wujiang

Wujiang (in Songling area)		**Middle Chinese tones**[8]			
	Initial type	I	II	III	IV
upper register (Yin)	voiceless unaspirated	55	51	412	55
"aspirated tone"	voiceless aspirated	33	42	312	33
lower register (Yang)	voiced	13	31	212	22

In Shen's (1994) acoustic study on a sub-dialect of Wujiang called Lílǐ, he shows that there is no need for a third "aspirated tone". His data confirm that voiceless aspirates align with voiced obstruents in terms of tone as they produce the same degree of low tone, in contrast to the high tone produced by voiceless unaspirated obstruents. There is, however, no further explanation of the mechanism of depressor aspirates that makes them always associated with low tones.

Bolyu is another language found in China that has voiceless aspirated depressors. The inclusion of Bolyu into Mon-Khmer is still subject to controversy (Benedict 1990, Edmondson & Gregerson 1996). All voiceless aspirates /p^h, t^h, k^h, q^h, h/ in Bolyu are depressors (Edmondson & Gregerson 1996:121). An example of an aspirated depressor is illustrated by [q^həp^{31}] "arrive", where tone "31" is a low falling tone.

2.3. Marked depressors – voiceless unaspirated depressors

Voiced obstruents in Bantu languages and Chinese Wu are phonologically considered to be truly voiced (e.g. Bradshaw 1999; Luo 1956) and thus they are expected to be unmarked depressors. However, phonetic studies reveal that some of the assumed voiced obstruents, as also reflected in orthography, are in fact voiceless. We therefore more aptly rename this special group of "voiced obstruents" as "voiceless unaspirated depressors" and start our examination of these depressors with Bantu before moving on to Chinese Wu.

2.3.1 Bantu languages

The major Bantu languages that have (marked) voiceless unaspirated depressors are isiZulu, isiXhosa, and siSwati, which all belong to the Nguni sub-branch of Bantu. This category of depressors in isiZulu includes orthographic /b, d, g, gǀ, gǁ, g!, v, z, dl, ɦ, dʒ, ŋ^{ǀɦ}, ŋ^{ǁɦ}, ŋ$^{!ɦ}$/ (Khumalo 1987:24-25); in isiXhosa /b, d, dʲ, g, v, z, ɣ, ɦ, dz, dʒ, gǀ, gǁ, g!, ŋ^{ǀɦ}, ŋ^{ǁɦ}, ŋ$^{!ɦ}$ / (Lanham 1958:74); and in siSwati /b, d, g, v, z, ɦ, dz, dʒ, ŋ[9], gǀ/ (Bradshaw 1999:86).[10] Apart from Nguni, it is noticed that Shona, a sub-branch within Bantu, also has voiceless depressors. Nambya (a Shona dialect) is a case in point. Unlike the Nguni languages which have orthographically

[8] Numbers 1-5 in the table indicate the pitch height from the lowest to the highest.

[9] /ŋ/ is said to be a reduced form of /ŋg/. /ŋg/ occurs stem-initially (e.g. ku-ŋgèéna "to enter") or follows the initial vowel of the stem (e.g.kw-eŋgàméela "to preside over"). /ŋ/ occurs elsewhere, either outside the stem or within a stem but not stem-initially. According to Rycroft (1976), prenasalised stops are breathy voiced.

[10] {c, x, q} refer to dental, alveolar lateral, and postalveolar clicks, respectively. The /g/ before the clicks {c, x, q} refers to the voiced version of clicks. For the full lists of consonant inventories in isiZulu, isiXhosa, and siSwati, see the appendix.

voiced stops being voiceless, in Nambya, there are voiceless fricatives, such as /f/, that can act both as non-depressors and as depressors, as in (7) below. Low tone is unmarked.

(7) Nambya non-depressor vs. depressor /f/ (Downing and Gick 2005)

Non-depressor /f/		**depressor /f/**	
[ku-fúmá]	"to become rich"	[ku-fumá]	"to sew"
[ku-fúndá]	"to learn"	[ku-fulíla]	"to thatch"
[ku-fá]	"to die"	[ku-filá]	"to spit"
[ku-fúpísa]	"to shorten"	[ku-fulá]	"to work metal"

However, reports on voiceless unaspirated depressors outside Nguni but within Bantu languages (e.g. Zambian Tonga (Carter 1962); Shona (Fortune 1955)) seem to be less robust than Nguni (Rycroft 1980). We now turn to Chinese Wu which is typical in having voiceless unaspirated depressors.

2.3.2 Chinese Wu

It is interesting to note that voiceless unaspirated depressors are not *sui generis* to Southern Bantu languages only, but are also found in Chinese Wu.[11] The voiced obstruents in Shanghainese are /b, d, g, dz̻, v, z, z̻/.

From the preceding data on Bantu, Khoisan and Chinese Wu, we now summarise depressors in the seven languages in (8). ("+" stands for depressors; "-" for non-depressors, and NA for the non-existence of the phonation type indicated.)

(8) Depressor patterns in the seven languages

Depressors / Languages	Unmarked		Marked		Nasals	
	voiced	any breathy	voiceless aspirates	voiceless unaspirates	nasals	prenasals[12]
Ikalanga	+	NA	+	-	-	-
Xitsonga	+	+	+	-	-	+
isiZulu	+	+	-	+	-	+
isiXhosa	+	+	-	+	-	+
siSwati	+	NA	-	+	-	+
Tsua	+	NA	+	-	-	NA
Shanghainese	+	NA	-	+	-	NA

[11]Apart from Chinese Wu, Zhong & Chen (2012) found that two sub-dialects of Xiang – Qiyang and Xinhua – also have "voiced stops" with no vibration in monosyllabic words.

[12] Prenasalised stops in Ikalanga are not breathy voiced and are non-depressors. Xitsonga are breathy voiced and are depressors. As for isiZulu, isiXhosa and siSwati, prenasals are not recorded in Khumalo (1987), but are recorded and recognised as depressors by Lanham (1958). However, whether their depression is triggered by voicing or breathiness is a controversy. Rycroft (1976) and Rycroft & Ngcobo (1979) treat prenasals as breathy voiced whereas Poulos & Msimang (1998) describe them as non-breathy-voiced. There are phonetic experiments testing the degree of voicing of voiced obstruents but unfortunately none yet that specifically investigates the laryngeal state of prenasals in these languages.

(8) presents a picture where all laryngeal/phonation types shown can act as depressors, i.e. voicing, breathiness, voiceless and aspiration all contribute to depressor effects. By contrast, nasal consonants do not act as depressors unless they are breathy voice. Thus, spontaneous voicing does not trigger depressor effects as also seen by the fact that in none of the languages are sonorants depressors. In all languages that have a voicing-breathy contrast, if the voiced sounds are depressors, then the breathy ones are too. For voiceless aspirates and voiceless unaspirates there is a split (3 v. 4) of languages where either of these sounds act as depressors or not but in no language do both act as triggers. Voiced and breathy sounds are thus the most unmarked triggers while, at least based on the current sample of languages, voiceless segments as depressor triggers are more marked whether they are aspirated or not.

3. Laryngeal settings of voiceless unaspirated depressors

Descriptions of the state of the glottis in voiceless unaspirated depressors in both Bantu and Chinese Wu are rather diverse and studies on this issue have been conducted over a long period of time. A complication of this type of depressor is that it contains both what have been historically treated as voiceless and "voiced" obstruents. As noted earlier, the latter set of obstruents orthographically represented as *b, d, g* have been confusingly described as either voiced or voiceless depressors by different authors, even for the same language.[13] This alternating representation is not only found for Bantu languages such as isiZulu, siSwati and isiXhosa, but also for Shanghainese Wu. Since these segments differ substantially from truly voiced stop depressors as, for example, found in Xitsonga, we follow the most recent studies in classifying them more accurately as "voiceless unaspirated depressors" in this paper. (9) illustrates the classification of voiced and voiceless depressors. In this section, we will review previous studies on these voiceless depressors and aim to provide a parallel overview of the development of how the state of the glottis for these depressors in both Bantu and Chinese languages has been interpreted.

(9)

voiced obstruents	**voiceless unaspirated obstruents**
i. truly voiced (DEP) *(Xitsonga, Tsua)*	iv. voiceless (nonDEP) *(Shanghainese, isiZulu, etc.)*
ii. "voiced" (DEP) *(isiZulu, isiXhosa, siSwati, Shanghainese)*	iii. voiceless (DEP) *(Nambya)*

i. voiced depressors
ii & iii. voiceless unaspirated depressors
iv. voiceless non-depressors

[13] Italicised *b, d, g* is always going to refer to these contentious sounds throughout the paper, i.e. those segments where there has traditionally been less agreement as to whether they are voiced or not. We also sometimes refer to these as "orthographic *b, d, g*". Our own conclusion, which is also the currently held consensus, is that these sounds are plain unaspirated voiceless. This of course does not change their orthographic representation in the literature and so we retain them in italics as *b, d, g* whenever this is necessary to give an accurate representation of what the literature refers to.

3.1 Bantu languages

Among the earliest studies on isiZulu, Beach (1924:80), cited in Traill et al. (1987), attributes depressors to the presence of voicing. This viewpoint was also shared by Lanham (1958:74) on isiXhosa and Ladefoged (1971:14) on Southern Bantu more widely. Ladefoged (1971) differs slightly in that although he treats both truly voiced depressors and orthographic *b, d, g* in isiZulu as having ordinary voicing, he concedes that the mode of vibration between the them is clearly different. Orthographic *b, d, g* in Southern Bantu languages like isiZulu are produced as murmur sounds, close to *bh, dh, gh* in Indo-Aryan languages, but their vocal cords are considered much more closely held together compared to Indo-Aryan languages, thus resulting in "more voice and less breath escaping". Colenso (1871:7) considers the same depressors *b, d, g* in isiZulu as fully voiced but also argues that there is slight aspiration associated with these sounds. Thus, according to Colenso, there are two types of voiced stops in isiZulu – plain voiced and aspirated voiced, with the latter being the equivalent of Ladefoged's murmured sounds. To exemplify with isiZulu, *bala* "it is" involves a plain voiced initial, while orthographically identical-looking *bala* "write" involves a voiced aspirated (or murmured) initial. Contrary to Colenso (1871), Doke (1923) argues that there is no such thing as an aspirated *b* in isiZulu. Instead he claims *b, d, g* are fully voiced and it is extra voicing that is mistakenly treated as aspiration. However, Doke (1926:50fn) later altered his point of view and adopted the term "voiced aspiration" for the *b, d, g* depressors and defined them as voiceless or not fully voiced. Doke (1963:10) later on offered a more precise description of *b, d, g* depressors as devoid of voicing during the stop phase, unless they are part of homorganic nasals *mb, nd, ŋg*.

The laryngeal status of *b, d, g* depressors in Nguni languages is also discussed in Lanham (1958, 1960, 1969). Contrary to Lanham's (1958) earlier findings, Lanham (1960:48-49) proposes in his PhD thesis that *b, d, g* in Nguni languages (isiXhosa, isiZulu, siSwati, and Ndebele) are marked by their voiceless quality up to the breaking of occlusion. These stops are immediately followed by a fortis release and strong voicing right after the occlusion. In isiXhosa, the fortis release is less prominent. However, *b, d, g* are fully voiced after a homorganic nasal, although the fortis release property is retained. Lanham (1969) modifies his 1960 analysis of isiZulu *b, d, g* and argues that both the onset and release are always voiceless. In addition, he claims that voicing in fact starts rather late, ±10 msec after the release, in contrast to the definition given by Chomsky and Halle (1968) for voiceless stops, where voicing substantially coincides with the stop release.

Cope (1966:22) defines *b, d, g* in isiZulu as voiced fortis. The "heavy voice" quality of these depressors is due to a co-operative effect of fortisness and voice. He conjectures that some unaccounted for distinctive feature such as [breathiness] might be the main cause of depression.

The term "breathy voice" is also frequently employed for *b, d, g* depressors in isiZulu, isiXhosa and siSwati. Tucker (1949:211) is the first to use the term "breathy" for voiceless depressors *b, d, g*, according to the literature we are aware of so far. The same terminology is also found in Rycroft (1980, 1981). Rycroft originally assigns a "low voicing" feature to all depressors in his 1976 siSwati textbook, which lowers pitch on the following vowel. In the absence of depressors, this "low voicing" feature could be present on vowels. He describes vowels with the "low voicing" feature as having "relaxed glottal tension, greater breath-flow, and relatively lower pitch (or H tones may take an initial rising onglide)". In his more cited paper, Rycroft (1980), he replaces the "low voicing" feature with a prosodic feature [depression]. This "depression" is a suprasegmental prosodic feature composed of "breathy voice" phonation on the vowel onset

(or the whole vowel). Fricative and sonorant depressors are breathy voiced (and also on the following vowel), whereas the depressors *b*, *d*, *g* in isiZulu are voiceless followed by breathy voice expressed on the following vowel (Rycroft 1980:15). Crucially, Rycroft (1980:3) proposes that "the actual consonantal voicing is not an essential concomitant of depression" since, first of all, not all voiced consonants are depressors (e.g. implosives) and secondly, there are cases of "depression without depressors". Instead, breathiness is an inherent property of the [depression] feature in all depressors. We agree with Downing (2009:183) that Rycroft (1980) to some extent over-emphasises the concomitant property of breathiness in depressors in Nguni languages and "misleadingly" characterises voiceless unaspirated depressors as "breathy voiced". As we will show in later sections, it is true that breathy voice is a concomitant feature for *b*, *d*, *g* depressors in Chinese Wu but not so for Nguni languages, although *b*, *d*, *g* are phonetically voiceless in both language families. Rycroft (1981) further classifies depressor *b* as a "post-breathy-voiced bilabial stop" in his Swati dictionary, amending his description of the articulation as "voiceless during occlusion with breathy voice release". He explains that his term "breathy" approximates most closely to Catford's (1977:32) "whispery voice" (rather than "breathy voice") and Ladefoged's (1971:8) "murmur" sound. Maddieson (2003) also uses the term "breathy" for *b*, *d*, *g* in siSwati. The table below is a summary of the above studies. One obvious tendency we can see from the table is that *b*, *d*, *g* depressors are more accepted as voiceless rather than truly voiced, with or without breathy phonation.

(10) Summary of studies on laryngeal settings of depressors *b*, *d*, *g* in Bantu

Events (Glottis state)	**Authors**	**Descriptions**	**Language(s)**
voicing	Beach 1924	voicing	isiXhosa
	Lanham 1958	voicing	isiXhosa
	Ladefoged 1971	ordinary voicing, but recognised the different vibration configurations for voiced and breathy voiced stops	Southern Bantu in general
	Rycroft 1976	low voiced	siSwati
	Doke 1923	fully voiced	isiZulu
voiced (occlusion + aspiration)	Colenso 1871	"slight aspiration" heard after *b*, *d*, *g* (similar to Ladefoged 1971)	IsiZulu
	Cope 1966	"voiced fortis", "heavy voice", voice+fortisness hypothesises "breathiness"	isiZulu
voiceless (occlusion) + aspiration (release)	Doke 1926	voiceless not fully voiced; "voiced aspiration"	isiZulu
	Doke 1963	devoiced during the stop unless preceded by homorganic nasals	isiZulu
	Lanham 1960	voiceless quality to the breaking of occlusion+immediate fortis release & strong voicing; different from "voiced aspiration (murmur)"	isiXhosa, isiZulu, siSwati, Ndebele
	Lanham 1969	both onset and release voiceless, voicing starts ±10 msec after the release	isiZulu
breathiness (i. over the onset or whole syllable	Tucker 1949	first to use "breathy" for depressor *b*, *d*, *g*	Sotho-Nguni in general
	Rycroft 1980	a prosodic depression feature with a breathy component on the vowel onset; voiceless with murmur release on the vowel onset	Nguni in general

ii. the onset offset and the vowel onset)	Rycroft 1981	clarified his 1980 proposal as voiceless during occlusion with a breathy release on the vowel onset	siSwati
	Maddieson 2003	breathiness, but not invariantly present for depression	siSwati

3.2 Chinese Wu

Chinese Wu has two groups of voiceless unaspirated obstruents: historically voiceless non-depressors and historically voiced depressors which evolved into voiceless depressors. The orthographic stops *b, d, g* in Chinese Wu fall into the second group. The earliest report on the glottis status of *b, d, g* in Chinese Wu is found in the work of the Chinese linguist and the New Culture Movement pioneer Liu Fu (1926), whose analysis is based on his experimental phonetics studies of Chinese tones. Liu was the first to notice that the stops *b, d, g* in Wu are in fact voiceless but with voiced aspiration.

Chao (1928:21, 27-28) agrees with Liu (1926), provides further precise descriptions on the voicing of *b, d, g*, and is the first to notice that voicing is environment-conditioned [also mentioned later on by Forrest (1948); Sherard (1972), among others]. Chao coined the term "qingyin zuoliu" (清音濁流) – "voiceless with voiced aspiration" – for Chinese Wu, which became widely accepted and used among Chinese linguists. He proposes that in monosyllabic words, the *b, d, g* in Wu are voiceless during occlusion but followed by voiced aspiration [ɦ]. Here we assume that the voiced aspiration [ɦ], described in Chao (1928), in essence resembles what Rycroft (1980) means by "breathy voice release" for Nguni languages. We can therefore conclude that their views on the glottal status of *b, d, g* in Chinese Wu and Nguni coincide. In terms of voiced fricatives, their onset is voiceless and gradually becomes voiced with some slight voicing aspiration. Hence [z], for example, is transcribed as [sz] or [sɦ] by Chao. Affricates are voiceless over the stop phase and also the onset of the fricative, but are voiced with [ɦ] aspiration from the middle of the fricative, thus [dzɦ] should be transcribed as [tszɦ]. Note that, although the term "qingyin zhuoliu" (清音濁流) is used to refer to all types of voiced obstruents in Wu, the duration of voicing is different from one type to another, with stops being completely voiceless during the occlusion but having voiced aspiration at release; while fricatives are only voiceless at the onset but not in the second half of the segment. By contrast, in intervocalic positions, all voiced obstruents are perceived as fully voiced.

Among earlier studies on Chinese Wu, Karlgren (1915-26) and Luo (1956) take a different view from Chao. Both authors consider the *b, d, g* stops in Wu to be truly voiced. Karlgren (1915-26/1940:168-196) notes that while there is full voicing during occlusion, there is also a slight aspiration [ɦ] during the release of *b*, similar to *bh* in Sanskrit. However, this [ɦ] is extremely weak and the segments could be regarded as voiced as a whole. He treats *b, d, g* as truly voiced without any trace of [ɦ]. Luo later alters this position in Luo & Wang (1981) and argues that the first half of the stop is voiceless but becomes voiced for the second half. Thus the stops *b, d, g* are transcribed as [pb, td, kg] [see Wang (1956) and Yuan (1960) for the same representation].

Apart from being voiced and/or voiceless, breathiness has also been commonly accepted as an explanation for the laryngeal setting of *b, d, g* depressors in Chinese Wu. Depending on individual analysis, the breathy quality is said to be persistent at the hold/release phase of stops,

or from the mid/mid-second half of a depressor to the following vowel onset, or throughout the whole onset or even across the entire syllable. For example, Ramsey (1987:90-91) argues that *b*, *d*, *g* in Shanghainese are produced with a breathy quality (or murmur), known as "voiced aspirates". This breathiness resembles the sound found in Indo-Aryan languages spoken in India and is acoustically prominent, pervading throughout the whole syllable.

Other researchers, such as Ren (1988, 1992), Cao and Maddieson (1992) and Chen (2015), assume that breathiness is consistently present on the following vowel onset of *b*, *d*, *g* depressors. More importantly, it is breathiness on the following vowel onset that directly triggers a low tone, rather than the depressors themselves. Cao (1982, 1987) and Cao and Maddieson's (1992) experiments on the Shanghai, Changshayin, Wenzhou and Ningbo dialects all show that there is no vibration for voiced obstruents during the occlusion. A further exploration of the difference between "voiced" and voiceless stops in Cao (1987) reveals that vowels immediately following the "voiced"/voiceless stops are of different phonation types. In Cao and Maddieson's (1992) experiments, they confirm Cao's (1987) findings and propose that the contrast between "voiced" vs. voiceless stops is in essence the contrast between breathy and normal voice quality realised on the following vowels (Cao and Maddieson 1992:9-11). The breathiness does not span over the whole duration of the vowel, but is prominent only in the onset. Cao and Maddieson (1992) argue that the breathy quality is neither attached exclusively to the stops as most phonologists assume, nor inherently on the following vowel. Rather, breathiness is triggered from the "voiced" stops and spreads to the following vowel through co-articulation.

More recently, Chen (2015) confirms Cao and Maddieson's (1992) findings through an EEG study to test whether *b*, *d*, *g* trigger breathiness and whether the breathy quality is subsequently spread to the following vowel through co-articulation.[14] Chen's findings show that it is not *b*, *d*, *g* depressors but the breathy quality expressed on the following vowel that directly contributes to a low tone in Shanghainese.

Ladefoged and Maddieson (1996:57-66) describe the depressors *b*, *d*, *g* in Shanghainese as "slack voice". They make a clear distinction between slack voice (marked by subscript /◌̬/) and breathy voice (marked by a superscript /ɦ/), according to the size of the glottal aperture and the amount of airflow. Breathy voice languages, such as attested in Indo-Aryan languages like Hindi and Marathi, have a larger glottal opening and higher flow rate than slack voice languages (e.g. Javanese and Shanghainese), which have only a slightly increased glottal aperture and a moderately increased airflow. The authors share the same view as Cao and Maddieson (1992) that voiceless depressors have a slack voice offset, which is detectable in the onset of the following vowels, but is not observable in the comparable portion of voiceless non-depressors. For example, in their spectrogram analysis of Shanghainese voiceless [p] (e.g. [pŏ] "half") vs. [b] ([b̬ŏ] "bowl"), they argue that the difference between [p] vs. [b] resides in the non-breathy vs. breathy quality of the vowel [ŏ].[15]

[14] EEG (electroencephalogram) is a commonly used technique/method in experimental work that detects the brain's electrical activity in brain cells using small electrodes that are attached to the scalp. For details on the experiment conducted, readers should consult Chen (2015).

[15] However, since they emphasise that the laryngeal setting of breathy voice is different from slack voice, and that Shanghainese voiceless depressors are slack voice, we expect to see the presence or absence of slack voice quality in the vowel [ŏ] rather than breathy voice.

Apart from the above analyses, the "slack voice" description from Ladefoged and Maddieson (1996) is also adopted in Jessen and Roux (2002), and Chen and Downing (2011) for voiceless unaspirated depressors in isiXhosa, isiZulu and Chinese Wu.

(11) summarises the above analyses on the laryngeal settings for voiceless unaspirated depressors in Chinese Wu. Comparing (10) with (11), it is interesting to notice that studies in Nguni and Chinese Wu have developed in similar ways where initially the stops *b, d, g* are considered as truly voiced and are the only or main depressors, but then followed by the discovery that these stops are essentially voiceless depressors. Discussions have also been similar between Bantu and Chinese Wu with the recognition of voiceless occlusion and aspiration release regarded as playing a role, followed by detailed studies of breathy or slack voice as also significant. A major difference is that breathiness is not consistently attested in Bantu voiceless depressors across speakers whereas, by contrast, breathiness is considered a salient feature in *b, d, g* depressors in Chinese Wu. (11) gives the phonetic features/states of the glottis assumed in the leftmost column with example languages in the rightmost column.

(11) Summary of states of the glottis of voiceless stop depressors in Chinese Wu

Events (Glottis state)	**Authors**	**Descriptions**	**Language(s)**
voiced (occlusion + release)	Luo 1956	voiced	Wu
voiced (occlusion) + aspiration (release)	Karlgren 1940	voiced occlusion + extremely weak [ɦ] at release	Wu
voiceless + voiced (occlusion)	Luo & Wang 1981, Yuan 1960; Wang 1956	voiceless in the first half, voiced in the second half	Wu
breathiness (i. over the onset or whole syllable ii. the onset offset and the vowel onset)	Liu F. 1913	voiceless with voiced aspiration	Wu
	Chao 1928, 1936	introduced 清音浊流 for "voiceless with voiced aspiration", environment-conditioned (≈Rycroft 1980's "breathy voice release")	Wu
	Ramsey 1987	"voiced aspirates", breathiness across the whole syllable	Shanghainese
	Cao 1982; Cao 1987; Cao & Maddieson 1992; Ren 1988; Chen 2015	breathiness on the following vowel onset	Shanghainese Changyinsha, Wenzhou Ningbo
slack voice	Ladefoged & Maddieson 1996	a slight increase in glottal aperture + a moderate increase in airflow (not breathy, which has a considerable glottal aperture+increase in airflow) but agree with Cao & Maddieson: voiceless + voiced breathiness following (phonation different at release), slack offset	Shanghainese

	Chen & Downing 2011	[slack voice], but isiZulu and Shanghainese have different phonetic implementations	(isiZulu) Shanghainese

In conclusion, in this section we have demonstrated that a number of studies show that voicing is not the only type of depressor. Depressors are rather diverse involving voicing, breathiness, plain voicelessness and aspiration. Whereas the first two factors belong to common unmarked depressors, the latter two are rather unexpected in terms of their laryngeal configurations and the number of attested languages that contain these depressors. This wide range of depressor types raises many challenges for phonological feature analyses, which we will discuss next.

4. Feature specifications for depressors

The above phonetic discussions of types of depressors indicate that the traditional feature [+voice] is not sufficient to explain depression because depressors cover a range of consonant types from voiced and breathy voice to voicelesss and aspirated consonants. Recognizing this, a number of proposals that aim to provide more adequate explanations have been offered in the literature. Below we examine some representative feature analyses proposed for Bantu, Khoisan and Chinese Wu.

4.1 Bantu and Khoisan languages

Nguni languages include voiced, voiceless unaspirated and breathy depressors. Khoisan languages, at least as shown in Tsua in Mathes (2015), include voiced and voiceless aspirated depressors. Our discussion starts from two classical assignments of laryngeal features, viz. Jakobson and Halle (1956) and Halle and Stevens (1971), which lay the foundation for later revised proposals specifically catering for voiceless unaspirated depressors. The features that are related to depressors in Jakobson and Halle (1956) are [tense] vs. [lax] and [voice] vs. [voiceless]. Therefore, voicing is represented by [+voice]. As for voiceless unaspirated depressors, Jakobson (1968:223) assigns the features [+voice, -checked, 0tense] for *b*, *d*, in isiZulu, ([tense] is not specified) but contrastively *g* is represented with the features [+voice, -checked, lax].[16]

Halle and Stevens (1971:203-207) recognise four fundamental laryngeal features [±slack], [±stiff], [±constricted glottis] and [±spread glottis], which yield 12 combinations in total (excluding the co-occurrence of [+slack] and [+stiff]). They follow a three-partition of obstruents into plain, aspirated and glottalised, with each group consisting of three types of obstruents. In this case, voicing is represented by [+slack, -stiff, -c.g, -s.g] (e.g. *b*, *d*, *g* in French). Plain voiceless unaspirated sounds are [-slack, +stiff, -c.g, -s.g] (e.g. non-initial English *p*). Fully aspirated sounds are [-slack, +stiff, -c.g, +s.g] (e.g. 'p^h, t^h' in Mandarin). Finally, breathy sounds are [+slack, -stiff, +s.g, -c.g] (e.g. *bh* in Hindi). Both Jakobson (1956) and Halle and Stevens (1971) offer little analysis on aspirated depressors in either Bantu or Khoisan languages.

Among the alternative feature proposals, Lanham (1969) adopts two binary features, [s-g pressure] and [voice], for depression. (12) gives the revised feature assignments for isiZulu in Lanham (1969).

[16] No further explanations are given on the different assignments of [tense] and [lax] to *b*, *d* and *g*. Breathiness is not mentioned in Jakobson's feature analyses, but we assume it might correspond most closely to [+voice, +tense].

(12) Lanham (1969) feature specifications for isiZulu

[s-g pressure]	[voice]	Lab.	Alv.	Alv Pal.	Vel.
-	+	ɓ			k
-	-	p	t	tsh	k’
+	+	b	d	j	g
+	-	ph	th		kh

In this case voiceless unaspirated depressors such as *b, d, g* are assigned features [+s-g pressure, +voice]. The feature [s-g pressure] represents heightened sub-glottal pressure that can be traced back to Chomsky and Halle (1968:324-5). This feature is attested in Lanham’s (1969) mouth tracing experiments where voiced and aspirated stops show sustained breath-stream pressure after release. Therefore, obstruents such as *b, d, g* in isiZulu are [+s-g pressure, +voice], voiceless aspirates are [+s-g pressure, -voice] and voiceless unaspirates are [-s-g pressure, -voice]. The [+/-s-g pressure] feature in Lanham’s kymographic study corresponds closest to Jakobson’s (1968) [tense/lax] where [+s-g pressure] correlates to heightened sub-glottal pressure and [tense] to increased intra-oral pressure. The reason for replacing [tense] with [s-g pressure] is that [tense/lax] could not be determined for plain voiceless unaspirated /p, t, ts^h, k’/ in isiZulu as the experiment conducted showed that they fluctuate with respect to tenseness, although /b, d, j, g/ and /p^h, t^h, k^h/ show a stable tendency for [+tense]. Voiced depressors in isiZulu are thus [+voice, +s-g pressure].

As discussed in section 3, Rycroft (1980:81) proposes a suprasegmental prosodic feature [depression] to capture depression, which contains a breathy phonation component for the vowel onset (or throughout the vowel if the tone is low). He assumes that [depression] is originally a linked property of all depressor consonants but also plays limited roles in cases where it occurs without depressors. Rycroft argues that the breathy phonation is always persistent on the following vowel onset regardless of depressor type. Although this feature may work for some ‘voiced’ depressors which are considered to have a certain degree of breathiness (e.g. isiZulu, Shanghainese), this is less so for languages whose voiced depressors lack any traces of breathiness (e.g. Xitsonga and Tsua).

Khumalo (1982:74) attributes depression to the feature [+slack vocal cords], which could be specified either on the syllable peak or on the consonant. This feature is employed for segments that are breathy voiced, though the degree of breathiness may vary quite considerably. Depressors in isiZulu are always underlyingly [+slack vocal cords]. All other segments are [-slack vocal cords]. However, the feature [+slack vocal cords] may also be added onto [-slack vocal cords] segments through the Slack Assimilation Rule in (13). The effect of this rule is to spread breathiness throughout the whole syllable, from a [+slack] segment to a following vowel, or from a vowel to a preceding vowel or sonorant consonant.

Vowels that are specified with [+slack] are marked with a special cedilla symbol. Segments that are [+slack] through the Slack Assimilation Rule are not expected to trigger depression because they are [-slack] underlyingly.

(13) Slack Assimilation Rule

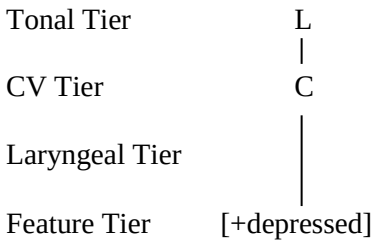
$$\rightarrow [+\text{slack}] \,/\, \left\{ \begin{array}{l} \_\_\_\ [+\text{slack}]; \\ \left[\begin{array}{l} \pm\text{vocalic} \\ \text{-obstruent} \end{array} \right] \\ [+\text{slack}]\ \_\_\_ \end{array} \right\}$$

(14) [+Slack] Assimilation

úmáɻmà	→	úmʱáɻmà	“mother”
únéʂì	→	únʱéʂì	“nurse”
léɻthà	→	lʱéɻthà	“bring!”
wóʐà	→	wʱóʐà	“come!”

Following Traill et al. (1987), Khumalo (1987:93) uses a similar feature [+depressed] for depressors. He offers a representational explanation for depressors where, on the one hand, depressors are dominated by the laryngeal tier with an underlying [+depressed] feature and, on the other hand, are linked to a low tone (L) on the tonal tier. This representation for depressors is given in (15). A similar Depressor Assimilation rule requires that the laryngeal feature [+depressed] and Low tone always spread automatically to the following vowels.

(15)



Traill et al. (1987) propose that an independent pitch-lowering [depression] gesture on all depressors is the primary and only reliable cause of depression in isiZulu. They tested this supraglottal laryngeal gesture in two experimental approaches: (i) pitch tracing and (ii) fibreoptic view of the larynx movements, from which they reveal a pitch-lowering gesture that starts during the voiced and voiceless stop depressors and ceases at the release of these stops. They argue that this depression adjustment involves an “anterior movement of the arytenoids” and a “posterior movement of the tubercle of the epiglottis”, which leads to a reduction of the lumen atero-posteriorly, and crucially induces an unusual degree of shortening of the vocal cords. This consequently results in a lowering of the rate of vibration. Since four out of seven subjects did not show this depression adjustment, they posit that other adjustments such as a crico-thyroid relaxation (observed in their experiments) or a change of the larynx height (not observed) could also contribute to the same effect.

Traill et al. (1987) point out that isiZulu depressors are unique because they include voiceless unaspirated depressors, which could not simply be explained by a single [depression] gesture. This is because the feature [depression] indicates shortened, relaxed and adducted vocal cords that naturally produce voicing rather than voiceless sounds. Therefore, they further assume that

there should be an extra [devoicing] gesture for voiceless depressors such as *b*, *d*, *g*. This [devoicing] gesture involves stiffening of the vocal cords, while at the same time maintaining the [depression] gesture. They believe that the stiffness and the shortening of the vocal cords are not mutually exclusive. To the contrary, this might support the proposal that "relaxation of the vocalis muscle leads to a reduction in the slackness of the cover of the vocal cords" [Hirose et al. (1974); Hutters (1985), cited in Traill et al. (1987:271)].

In summary, Traill et al. (1987) propose the following features, given in (16), for depression. A universal [depression] gesture is present across all depressor types, but other gestures vary depending on specific depressor types.

(16) Truly voiced depressors:
(i) [depression]: shortening/slackening of vocal cords, accompanied by a relaxation of the vocalis muscle and adducted vocal cords

Voiceless unaspirated depressors *b*, *d*, *g* in isiZulu:
(i) [depression] and,
(ii) a devoicing gesture (stiffened vocal cords)

Note that Traill et al.'s analysis implies that there are only two types of depressors in isiZulu – voiced and voiceless unaspirated depressors. Crucially they disagree with the argument given by Rycroft (1980) that breathiness is a compulsory component of depressors. Their laryngographic tracings show that breathiness is not consistently present in all depressors across all subjects, at least in isiZulu. Neither is it always captured on the following vowel onset of the depressors. Instead, the breathy quality is found during the hold phase of some stop depressors and even in non-depressors. Hence, they conclude that breathiness might co-occur with the depression gesture and may even spread to the following vowel through co-articulation (although minimal), but it is by no means a "reliable concomitant of depression" (Traill et al. 1987:270).

One issue with Traill et al.'s analysis is that their [depression] and [devoicing] gestures are to some extent contradictory. First of all, it seems that vocal cord "shortening" and "slackening" are interchangeable and this is also confirmed in Traill et al. (1987), where they adopt both terms in their descriptions of the [depression] gesture.[17] If this is so, the [devoicing] gesture, viz. the "stiffening of the vocal cords", should be incompatible with the [depression] gesture which refers to "slackening" or "shortening" of the vocal cords. However, when discussing the gestures for voiceless depressors in isiZulu, they explain that the combination of [depression] and [devoicing] is not mutually exclusive. One solution is that "slackening" and "shortening" bring different effects and what Traill et al. actually mean is "shortening", not "slackening", for the [depression] gesture. This is exactly how Strazny (2003) deals with voiced and voiceless depressors in his analyses of isiZulu. Strazny (2003) proposes three contrastive feature pairs that aim to explain both depressor and anti-depressor interactions with tones. The feature pairs are illustrated in (17).

[17] For the terms "shortening" and "slackening" as used here, see Traill et al. (1987:265, 271).

(17)

Tone	**Articulatory gestures**	**Features**	**Targets**
H	cricothyroid tensing	i.[tense v.f] ([increased longitudinal vocal fold tension])	anti-depressors
	posterior arytenoid movement	ii.[stiff v.f]	
	suprahyoidal tensing	iii.[raised larynx]	
L	cricothyroid laxing	i.[lax v.f] ([decreased longitudinal vocal fold tension])	depressors
	anterior arytenoids movement	ii.[slack v.f]	
	strap muscle tensing	iii.[lowered larynx]	

(adapted from Strazny 2003:231)

Unlike previous single feature analyses, Strazny argues that tonal categories (H&L tones) are cover terms for more than one articulatory gesture, because tone lowering and raising effects are realised by the joint work of many muscles rather than one single articulatory gesture, although it is not necessary to have the presence of all gestures simultaneously.

Strazny's feature set analysis successfully unifies feature specifications for depressors and anti-depressors. Recall that in Traill et al. (1987), voiceless unaspirated depressors in isiZulu are specified by [depression] and [devoicing] features. In Strazny, his [slack v.f] corresponds to the [depression] feature in Traill et al. and is employed for truly voiced depressors. The feature [devoicing] is replaced by a new feature pair [lax v.f] and [tense v.f] to represent voiceless unaspirated depressors *b*, *d*, *g* and anti-depressors respectively.[18] Strazny differentiates vocal fold "slackening" from "shortening", where the former gesture is interpreted by [slack v.f] and the latter by [lax v.f]. A comparison between Traill et al. (1987) and Strazny (2003) is given in (18).

[18] The features [lax v.f] and [tense v.f] are adopted from Shryrock's (1995:69-73) feature analysis for anti-depressors in Musey (a Chadic language). Musey anti-depressors are phonetically heterogeneous, including both voiced and voiceless obstruents. Shryrock proposes that an increase in the longitudinal tension of vocal folds is the primary cause of F0 raising (H tone), which is represented by [tense v.f] in Strazny (2003). The opposite gesture, a decrease in the longitudinal tension (or shortening of the vocal folds), is represented by [lax v.f].

(18) Feature representations in Traill et al. (1987) and Strazny (2003)

	Traill et al. (1987)		**Strazny (2003)**	
truly voiced depressors	[depression]:	vocal folds shortening/slackening	[slack]: [lax v.f]:	vocal folds slackening vocal folds shortening (decrease in longitudinal tension of the vocal folds)
voiceless unaspirated depressors *b, d, g*	[devoicing]	vocal folds stiffening	[lax v.f]:	vocal folds shortening (decrease in longitudinal tension of the vocal folds)

Maddieson (2003:30) agrees with Traill et al. (1987) that true depression consists of a special laryngeal gesture consistent with very low pitch co-produced with the consonant it is associated with. Maddieson argues that this [depression] gesture is expected to be linked with any consonants and thus should be recognised as an independent phonological entity. He distinguishes non-depressors from depressors in siSwati through the observation that depressors have "noticeable breathy phonation during part of the consonant and at the vowel onset". But he also recognises that "breathiness is not an invariable accompaniment of depression", which we believe he erroneously attributes to Rycroft (1980), for whom "breathiness" is an indispensable part of his feature [depression]. What Rycroft (1980:3) actually posits is that "consonantal voicing is not an essential concomitant of depression", although of course breathiness subsumes some voicing component.

Jessen and Roux (2002) employ [slack voice] for depressors. They propose that extensive larynx lowering is the primary posture for voiceless unaspirated depressors in isiXhosa, which results in vocal fold slackening.[19] In line with Kingston (1985) and Denning (1989) they argue that if the slackening of the vocal folds reached a certain threshold, the transglottal airflow would become so high that it would work against the maintenance of closure voicing, thus producing optional glottal leakage (breathy voice) and finally devoiced sounds. At the same time, the extensive vocal fold slackening causes F0 lowering and additional F1 lowering. In this case, the lack of voicing in voiceless unaspirated depressors in isiXhosa is compensated for by the low F0, F1 and optional breathy voice. The same phenomenon was also noted in corresponding voiceless unaspirated depressors in Shanghainese for which a parallel analysis is adopted.

Chen and Downing (2011) agree with the same feature [slack voice] but differ from Jessen and Roux (2002) in that they argue that the same phonological feature [slack voice] characterises segments with different phonetic implementations in isiZulu and Shanghainese, due to the different phonologies of the two languages. Nevertheless, they agree with Jessen and Roux (2002) that breathiness is not an invariant factor in depression.

Downing and Gick (2005), also noting the unnaturalness of depressors in Ikalanga and Nambya, speculate that a new phonetic correlate, possibly longer duration of frication noise, should be introduced to account for F0 lowering in voiceless depressors.

[19] Recall that larynx lowering was not observed in isiZulu depressors in Traill et al. (1987).

4.2 Depressor feature representations in Chinese Wu

As discussed in section 3, "phonation-induced low tone" is the mainstream analysis of Shanghainese Wu depression, which says that (breathy voice) phonation on the vowel onset begins after the depressor causes low tone. Depressors themselves are regarded as having little direct relation to low tone in depression. Therefore, fewer features have been proposed to specifically account for depressors in Chinese Wu compared to Bantu [e.g. [slack voice] for Shanghainese by Jessen and Roux (2002)]. The different proposed feature analyses for Shanghainese appear in the shaded cells in (19).

In contrast to Chinese, feature analyses in Bantu are more diverse owing to the variant presence of breathiness [e.g. Rycroft (1980); Traill et al. (1987)]. In addition, analyses of Bantu are depressor-induced oriented, resulting in a wide range of features proposed in line with the attested depressor type [e.g. Khumalo (1981:87); Traill et al. (1987); Strazny (2003)]. Thus, although Bantu and Chinese Wu share the same type of voiceless unaspirated depressors, differences in the conceptualisation of the source of depression has resulted in differing analyses.

(19) Features for depressors in Bantu and Chinese Wu

Events (Feature specifications)	**Authors**	**Descriptions**	**Language(s)**
classical laryngeal feature specification (general)	Jakobson 1968	*b*, *d*: [+voice, -check, 0tense] *g* [+voice, -checked, +lax]	isiZulu
	Halle & Stevens 1971	breathy = [+slack, -stiff, +s.g, -c.g]	in general
an inherent [low tone] on depressors	Lanham 1960	DEP = voiced consonants + inherent low tone	Nguni
	Khumalo 1987	DEP = [depression] + low tone	isiZulu
[low voicing]	Rycroft 1976	relaxed glottal tension, greater breath-flow, and relatively lower pitch	siSwati
[depression]	Rycroft 1980	a prosodic feature comprised of "breathy" voice quality on the following vowel onset (or the whole vowel); a feature realizable over the syllable rather than a single segment	Nguni in general (incl. isiZulu, siSwati, isiXhosa)
	Traill et al. 1987	a feature [depression] (which Chen & Downing treat as equivalent to [slack voice])	isiZulu
	Khumalo 1987	in line with Traill et al. 1987, [depression]	isiZulu
	Maddieson 2003	in line with Traill et al. 1987, [depression], breathiness but not a consistent concomitant for depression	siSwati
[slack voice] [slack vocal cords]	Khumalo 1982	for all DEPs that are breathy voiced	isiZulu
	Ladefoged and Maddieson 1996	a slightly increased glottal aperture + a moderate increase in airflow	Shanghainese

	Jessen & Roux 2003	the same definition as in Ladefoged & Maddieson 1996, triggered by larynx lowering, breathy optional	isiZulu, Shanghainese
	Chen & Downing 2011	isiZulu and Shanghainese have different phonetic implementations due to their different tonal phonologies	isiZulu Shanghainese
[breathiness]	Cao & Maddieson 1992	breathiness on vowels	Chaoyinsha, Shanghai, Wenzhou etc.
	Chen 2015	breathiness on vowels	Shanghainese
feature pairs	Strazny 2003	depressors: [lax. v.f] anti-depressors: [tense. v.f]	isiZulu vs.Musey
[+slack]	Mathes 2015	aspirated depressors	Tsua

Despite the difference between the two approaches to depressors in Chinese and Bantu, one commonality is that the phonological features used are in each case defined based on the varying articulatory phonetic details. A central characteristic is that all depressors have an element of voicing or breathiness with phonetic variation as to whether these are part of the consonant closure or release, or the following vowel onset. Future work will need to provide more broad phonological representations from which these differing phonetic implementations can follow. Our own approach would favour more cognitive based phonological features with broad acoustic interpretation which can then be malleable to language-specific phonetics.

5. Conclusion

This paper brings together depressor studies in the literature to provide a comparative study between Bantu, Chinese Wu and, to a lesser extent, also Khoisan, focusing on the diversity of depressors in terms of depressor types, laryngeal settings and feature specifications. We observed in the investigation of the different glottal states that voiced, breathy, voiceless and aspirated sounds can all be possible triggers of depression. But crucially the different phonetic studies show that in the case of voiceless and aspirated depressors, there is an additional element in the laryngeal specification of these sounds that distinguishes them from truly voiceless (unaspirated and aspirated) non-depressors. We also examined the different phonological features that have been proposed for depressors, noting that Bantu language analyses opt for a depressor-induced approach, whereas analyses of Chinese Wu follow a phonation-induced approach. For depressor-induced analyses, a close relation between the consonant and the vowel is mandatory to effect depression, supporting a strong consonant-tone interaction that any analysis would have to take into account.

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Appendix – Shanghainese, isiZulu, isiXhosa, and siSwati consonant inventories

Data are drawn from Zhu (2005) for Shanghainese; Lanham (1960), Rycroft (1979) & Khumalo (1981, 1987) for isiZulu; Lanham (1958, 1960) for isiXhosa; and Rycroft (1976), Bradshaw (1999) & Lanham (1960) for siSwati.

Shanghainese consonant inventory

	Bilabial		**(Labio) Dental**		**Alveolar**		**Alveolar -palatal**		**Palatal**	**Velar**		**Glottal**	
Stops	p	b			t	d				k	g	ʔ	
	pʰ	ɓ			tʰ					kʰ			
Nasals	m				n				ɲ	ŋ			
	m̤				n̤				j̈	ŋ̈			
Approx.	w				l				j				
Fricatives			f	v	s	z	ɕ	ʑ				h	ɦ
Affricates					ts		tɕ	dʑ					
					tsʰ		tɕʰ						

isiZulu consonant inventory

	Bilabial		**(Labio) Dental**		**Alveolar**		**Alveolar -lateral**	**Palatal**	**Velar**		**Glottal**	
Stops/ implos	p(’)	b			t(’)	d			k(’)	g		
	pʰ	ɓ			tʰ				kʰ			
Nasals	m				n			ɲ	ŋ			
	m̤				n̤			j̈	ŋ̈			
Prenasals	mb				nd				ŋg			
Approx.	w				l			j				
	ẉ							j̈				
Fricatives			f	v	s	z	ɬ, ɮ	ʃ			h	ɦ
Affricates								tʃ dʒ				
Clicks			ǀ gǀ ŋǀ				ǁ gǁ ŋǁ	ǃ gǃ ŋǃ				
			ǀʰ ŋǀʱ				ǁʰ ŋǁʱ	ǃʰ ŋǃʱ				

isiXhosa consonant inventory

	Bilabial	**(Labio) Dental**	**Alveolar**	**Alveolar -lateral**	**Palatal**	**Velar**	**Glottal**
Stops/ Implosive	p(’) b p^h ɓ		t(’), t^j d, d^j t^h, t^{jh}			k(’) g k^h	
Nasals	m m̤		n n̤		ɲ n̈	ŋ ŋ̈	
Prenas	mb		nd			ŋg	
Apprx	w w̤		r r̤	l l̤	j j̈		
Fricatives		f v	s z	ɬ, ɮ	ʃ	ɣ	h ɦ
Affricates			ts dz ts^h		tʃ dʒ $tʃ^h$	kx	
Clicks		ǀ gǀ ŋǀ $ǀ^h$ ŋǀ^ɦ		ǁ gǁ ŋǁ $ǁ^h$ ŋǁ^ɦ	! g! ŋ! $!^h$ ŋ!^{ɦ}		

siSwati consonant inventory

	Bilabial	**(Labio) Dental**	**Alveolar**	**Alveolar-lateral**	**Palatal**	**Velar**	**Glottal**
Stops/ Implosives	p(’) b p^h ɓ		t(’) dl t^h			k(’) g k^h	
Nasals	m		n		ɲ	ŋ	
Prenasals	mp mb̤	mf mv̤				ŋg̈	
Approx.	w		l		j	kl	
Fricatives		f v	s z		ʃ		h hl ɦ
Affricates	dv		dz		tʃ dʒ		
Clicks		ǀ gǀ ŋǀ $ǀ^h$ ŋǀ^h ŋ̈ǀ ŋg̈ǀ					