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Interaction of phonation and tone in Nuer

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This article presents a case of allotony based on the phonation of the vowel in Nuer, a Western Nilotic language; the falling tone is found only on modal vowels in this language, while the high level tone is found only on breathy vowels. We describe the phenomenon and present evidence suggesting that it may be due to the neutralization of two separate tonal contours, H and HL, conditioned by the phonation of the vowel. We place this phenomenon within the known typology of phonation-tone interaction and advance a proposal as to the phonetic factors behind its development.

Keywords: phonation; tone; Nilo-Saharan; Nuer

1 Introduction

Nuer, a West Nilotic language indigenous to South Sudan and the Gambela region of Ethiopia, manifests contrastive phonation in its vowel inventory. As shown in Figure 1, all vocalic phonemes except /ʌ̤/ come as a modal/breathy pair. The phonemes in Figure 1 occur in three length degrees: short, long, and overlong.[1]

a. Monophthongs	b. Diphthongs
i̤ ṳ	i̤e̤ ṳɔ̤
ɪ ʊ	ɪɛ ʊɔ
e ɵ	
e̤ ɵ̤	
ɛ ɛ̤ ɔ ɔ̤	ɛa ɛ̤a̤ ɔa ɔ̤a̤
ʌ̤	
a a̤	

Figure 1: Nuer vowel inventory

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[1] Here we follow a convention established in West Nilotic literature (see, for example, Andersen (1990, 1992, 1993), Remijsen & Manyang (2009), and Storch (2005), among others) of representing vowel length by doubling or tripling the vowel grapheme, rather than using the IPA notation for this particular feature. In diphthongs, the second grapheme of the diphthong is doubled or tripled to reflect its length (i.e., an overlong diphthong consists of four graphemes). Breathiness and tonal properties indicated on the first grapheme of the vowel apply to the whole syllable.

Recent research shows that the tonal system of Nuer possesses an inventory of five possible tonal contours: high, low, rising, falling, and mid (Monich 2019, 2020; Reid 2019). These five tonal contours are found on all vowels irrespective of quality and length. The actual number of tonemes, however, is smaller, as some of the five tones are allotones of the same toneme. It is argued in Monich (2020) that the tonemic inventory of Nuer is comprised of the Low, the Rising, and the High tonemes. The contrast between these three tonemes is illustrated in Figures 2–4 using monosyllabic nominal forms in phrase-medial position.

tîɛɛɛm-ʌ̤̀	**t̪ɔ̤́ɔ̤n**	kɛ̀	t̪jâŋ
remember.TR-1SG	serval.PL.NOM[2]	PREP	evening

‘I remember servals in the evening.’

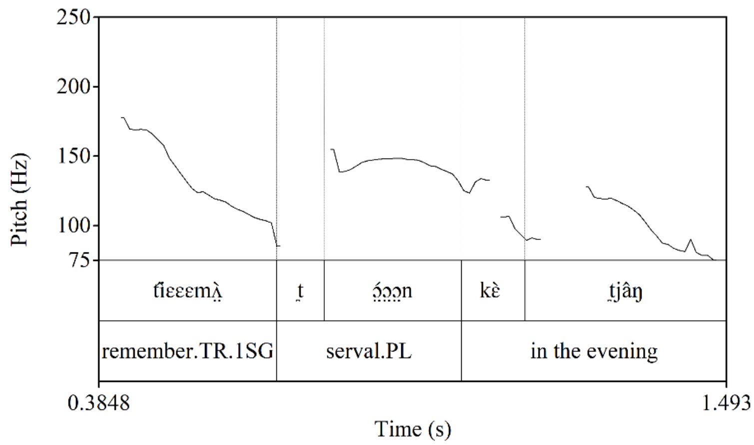

Figure 2: The High toneme in the stem of the form /t̪ɔ̤́ɔ̤n/ ‘serval.PL.NOM’

tîɛɛɛm-ʌ̤̀	**t̪ɔ̤̀a̤a̤n**	kɛ̀	t̪jâŋ
remember.TR -1SG	serval.SG.NOM	PREP	evening

‘I remember a serval in the evening.’

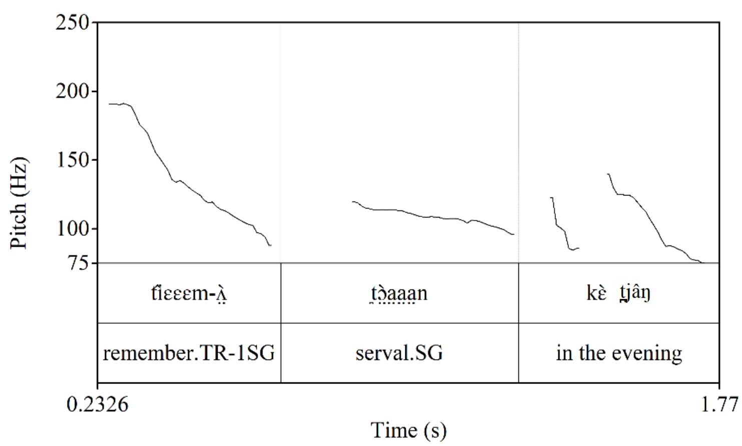

Figure 3: The Low toneme in the stem of the form /t̪ɔ̤̀a̤a̤n/ ‘serval.SG.NOM’

[2] Nuer has three cases: Nominative (NOM), Genitive (GEN) and Locative (LOC). Only the oblique cases (GEN and LOC) are indicated in pitch-tracks.

tîɛɛɛm-ʌ̤̀ **lĕ̤e̤e̤k** kɛ̀ t̪jâŋ
remember.TR-1SG fish (sp.).PL.NOM PREP evening
'I remember tilapia in the evening.'

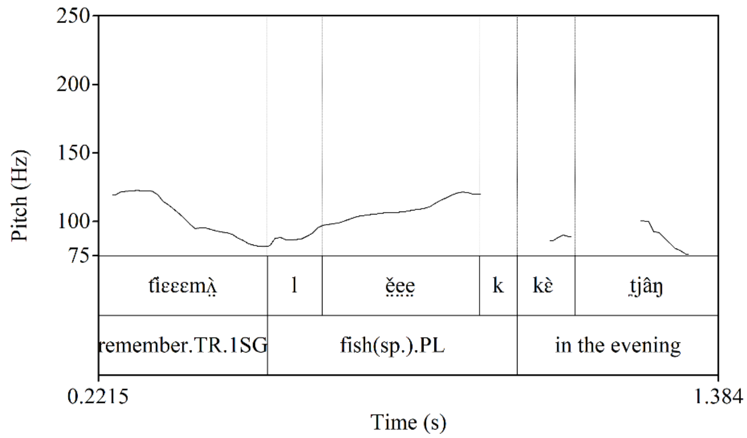

Figure 4: The Rising toneme in the stem of the form /lĕ̤e̤e̤k/ 'fish (sp.).PL.NOM'

The Low toneme is the only toneme without allotonic variants: it is realized with a low tone in all contexts. The Rising toneme has a low allotone phrase-finally and also a mid allotone that is a near-free variant of the rising allotone.[3] Finally, the High toneme has a high level allotone and a falling allotone – this allotonic variation is the focus of this article.

All examples in Figures 2-4 above employ monosyllabic nominal forms with overlong breathy vowels in the stem. Vowel length is largely immaterial for the realization of the tonal contour: short, long, and overlong vowels can be associated with any one of the possible five tonal contours. Voice quality, on the other hand, is a factor that turns out to be highly relevant to the realization of the High toneme: it is executed as a high level tone over breathy vowels only, as in Figure 2; over modal vowels, on the other hand, the High toneme is always realized with its falling allotone.[4] This typologically unusual case of interaction between phonation and tone is of potential interest to phonologists.

The correlation between pitch contour and vowel phonation in Nuer was made in Monich (2019, 2020) but has gone unnoticed in the earlier literature on this language. Both high and falling tones are transcribed in Crazzolara (1933) without further comment on their distribution. Frank (1999) and Faust (2015) do not transcribe tonal properties. Gjersøe (2016) identifies a falling tone but posits it as a separate toneme contrastive with a high tone. Inconsistent transcription of either the breathy phonation or the falling tone in these works obscures the relationship between tone and voice quality. Two recent studies – Gjersøe (2019) and Reid (2019) – confirm a correlation between the realization of tone and vowel phonation made in Monich (2020). Reid, who generally agrees with the tonal inventory proposed in Monich (2020), treats the Rising toneme (which has a mid allotone in my system) as a Mid toneme with a rising allotone. The correlation between tone and vowel phonation is drawn less forcefully in Gjersøe (2019), who states that HL tone is impossible on breathy vowels without claiming that the reverse is also true, i.e., the H tone is only possible on modal vowels.

[3] In most circumstances, the rising tone can be realized as a mid tone and vice versa. There are a few contexts, however, when one of the two allotones is obligatory: for example, before a falling tone, the Rising toneme must be realized with a rising tone and not with a mid tone.

[4] The Rising toneme can also be realized with a falling allotone over modal vowels but only in specific tonal contexts, where it is converted to a High toneme due to tonal sandhi (usually as a result of contour simplification following another Rising toneme). As such, the realization of the Rising toneme as a fall is subsumed under the phenomenon of the phonation-based allotony of the High toneme and does not receive separate treatment here.

The main objective of this work is to bring the phenomenon of phonation ~ tone interaction in Nuer to the attention of phonologists outside of the Nilo-Saharan sub-area of linguistics. Unlike Monich (2020), which establishes the basic facts regarding Nuer tonal inventory, the present article focuses specifically on the allotonic variation between high level and falling tones. Its goal is to demonstrate conclusively that tone and phonation interact in Nuer and investigate the nature of this interaction. In particular, this article offers evidence suggesting that the phonation-based complementary distribution of high level and falling tones is due to the neutralization of two underlying tonal melodies – H and HL – rather than from allotonic variation of a single toneme H, as presumed in Monich (2020). Additionally, this article offers a possible explanation for the unusual relationship between tone and phonation by examining phonetic clues and considering this relationship in a greater typological context.

2 Methods

The phenomenon described in this article has been established based on original Nuer data elicited in collaboration with twelve consultants over the course of five years.

The consultants used for this study are all native speakers of Nuer, born in South Sudan but forced to flee their country of birth as teenagers or adults due to civil strife. All currently reside outside of South Sudan (UK and USA) but are members of close-knit Nuer-speaking communities and use Nuer on a daily basis. Although most left (South) Sudan in the 1990s, they maintain a close connection to family members in South Sudan and the surrounding refugee communities in Ethiopia, Kenya, and Sudan. Many, if not all, visit Nuer-speaking communities in Africa, especially for social occasions such as weddings. Some consultants have minimal knowledge of English; for all, English remains a secondary language of communication in their daily lives.

Four of the twelve consultants represent the Western variety of Nuer (Bentiu), while eight are speakers of the Eastern dialect of Nuer (Jikany). Of those eight, all but one are speakers of the Gajiok variety of the Jikany dialect, with the remaining one representing the Gajiak variety. One of the seven Gajiok Nuer consultants spent his formative years in the Akobo area of South Sudan (where the Lou variety of Nuer is spoken) but currently speaks the Jikany dialect, having lived among Jikany speakers most of his life. His judgments were in agreement with the other Jikany Gajiok speakers. Although our consultants belong to two major dialectal groups, we observed no dialectal differences regarding the tonal phenomenon discussed here. Nasir Gajiok dialect of Nuer is used to transcribe all examples in this article.

All nouns were elicited by having consultants translate frames that placed nominal forms in identical environments. In order to control for phrase-final effects, all frames were elicited with and without a final adjunct (‘in the evening’ or ‘now’). The nominative case was elicited using three frames ‘I remember/see X (in the evening),’ ‘I bought/saw/followed X,’ and ‘I do not buy/see/follow X.’ For most of the animate items, two more frames were used, with the noun appearing as a post-verbal subject (‘X swims (TR) the river’ and ‘X swims (AP) in the river). Many nominative case forms were elicited in isolation also, and some in additional frames as objects of imperatives (‘kill X!’, ‘buy X!’, ‘eat X!’ etc.). The genitive forms of all nouns were elicited in the frame ‘I want to think of X (in the evening)’ and also, for many of the animate nouns, using frames ‘bone of X/meat (sg.) of X/ meat (pl.) of X.’ The locative forms of those nouns that have them (semantic locations) were elicited using two frames: ‘I run to X (in the evening)’ and ‘He is at X (in the evening).’ The transcribed list of the frames used in elicitation is provided in Appendix A.

All inflected verbal forms were elicited in the context of a preceding subject pronoun and the following object (*rǎaan* ‘person/someone’ or *dwɔ̤̌ɔ̤ɔ̤r* ‘thing/something’) or an adverb (*ɛ̀ntɛ̂mɛ̀* ‘now’), as well as in isolation.

Although this study is based on observations made in working with 12 individuals, only one individual’s speech was used for pitch tracks and measurements to keep factors such as individual pitch range constant. This individual is a male in his 40s, a native speaker of the Gajiok variety of Jikany Nuer. He immigrated from South Sudan to the USA in the 1990s but continues to maintain close ties to his family in South Sudan and to be active in the local community of South Sudanese expatriates. He employs Nuer daily as his primary language outside of the work environment.

3 Relevant aspects of Nuer phonology

3.1 Phonemic inventories and syllable structure

To reiterate, the vowel inventory (shown in Table 1) consists of 15 monophthongs and eight diphthongs. All monophthongs (except for /ʌ̤/) and diphthongs can be organized as pairings of a modal vowel and its breathy counterpart. The property of breathiness ultimately derives from the [+ATR] property of ancestral vowels and is still loosely correlated with this property in present-day Nuer, even though this correlation is no longer perfect. Voice quality is a property that is notoriously difficult to transcribe for non-native speakers. However, most vowels have several other acoustic correlates distinguishing the breathy and the modal counterparts. For example, high breathy vowels are tenser than modal high vowels, while breathy close-mid vowels are perceptibly lower than the corresponding modal ones. For those phonemes where breathiness is not paired up with other phonetic properties in opposition to their modal counterparts (for example, /a̤/ vs. /a/ and /ɔ̤/ vs. /ɔ/), the contrast in phonation is also the most perceptible, even to a non-native speaker (see Section 6 for details).

All vowels – diphthongs and monophthongs – have short, long, and overlong variants. The first segment of a diphthong is practically dropped in short syllabic nuclei; similarly, a glide in the onset vocalizes in long and overlong nuclei. These details are unimportant for the discussion of tone and therefore ignored by transcription conventions used in this article. In general, the tone of the syllable is not directly determined or constrained by the syllable structure.

The consonantal inventory of Nuer is shown in Table 1. The phonemes in parenthesis appear in stem-final position in some varieties of Western Nuer but are non-contrastive in Eastern Nuer. The consonant /ɦ/ is usually transcribed as <ɣ> in Nuer literature. However, the nature of this consonant is elusive – in the speech of some speakers, it is realized only as a light puff of air or may even be completely absent.

Table 1: Nuer consonantal inventory

	Labial	**Dental**	**Alveolar**	**Palatal**	**Velar**	**Glottal**
Voiceless stops	p	t̪	t	c	k	
Voiced stops	b	d̪	d	ɟ	g	
Voiceless fricatives	(f)	(θ)	(r̥)	(ç)	(x)	
Voiced fricatives		(ð)			(ɣ)	ɦ
Nasals	m	n̪	n	ɲ	ŋ	
Lateral			l			
Trill			r			
Glides	w			j		

Almost all native Nuer roots are of structure C(G)VC where C represents any consonant (except those shown in parentheses in Table 1) and G represents an optional glide. The root may be followed by a single segmental suffix of -(C)V structure. All other affixes are non-segmental and consist of floating morae and features. Consequently, non-compound native words are maximally disyllabic.

3.2 The main features of the tonal system

Nuer nouns, which do not appear to be modified through non-concatenative morphology,[5] show a three-way tonal contrast that is independent of vowel length: *tǒʊl* 'smoke', *tîɪk* 'bead', *ṯá̤ʌ̤k* 'ox', *rěc* 'fish', *ṯí̤k* 'chin', *rîp* 'fishing blade'. Tonal specification of verbal roots is uncertain due to the fact that in all verbal forms, the root appears morphologically modified – either by derivational or by inflectional non-concatenative morphology – and the tonal contour of the verbal root, along with the properties of the root vowel and the root-final consonant, is a by-product of this modification. However, it is clear that in the verbal system, the lexical properties of tone and vowel length are intrinsically tied together as roots with short and long vowels belong to different inflectional classes and follow divergent patterns in both tone and vowel quantity.

Root syllables are found associated with a Low toneme only when they are morphologically non-basic: for example, *mi̤ḛm* '(a single) hair', *(µ)càk* 'tick' (cf. WN *(µ)càx* 'tick'),[6] *bʌ̤̀l* 'jump over.MULT' (<*bʌ̤ʌ̤l)*, *rɔ̀aaam* 'sheep'. In these examples, various mutated properties of the root – changed root vowel quality, spirantized root-final consonant, shortened root vowel, and lengthened root vowel correspondingly – signal that these low-toned forms incorporate non-concatenative morphology.

Segmental affixes (both nominal and verbal) are not lexically specified for a particular tonal value: the same segmental affix may be associated with a high/falling or with a low tone depending on the morphological make-up of the base. Most commonly, the suffix is assigned a tone polar to the first tonal autosegment of the root syllable. The two nominal suffixes – the plural suffix *-ni̤* and the genitive singular suffix *–(k)ʌ̤*[7] – are assigned a high tone after a stem that carries a low or a rising tone (L or LH) and a low tone after a stem that carries a high or a falling tone (H or HL). For example, a genitive singular form derived from the nominative singular form *(µ)càk* is *(µ)càk-ʌ̤́*, with a high tone on the suffix following the low tone on the root. The same suffix has a low tone in a genitive singular form *ɟó̤p-ʌ̤̀* derived from the nominative singular form *ɟó̤p* 'ax,' as it follows a high tone in the root.

In verbs, subject agreement suffixes are also assigned tone that is polar to the first tonal autosegment of the root syllable in all derived paradigms: the subject agreement suffix carries the High toneme after stems associated with low and rising tonal contours (L or LH),[8] and the Low toneme after stems associated with high and falling tonal contours (H or HL). Here are some examples of inflected verbs from various derivational classes illustrating this pattern: *lḛ̌ḛb-í̤* 'open.MULT-2SG', *bʌ̤̀ʌ̤ʌ̤l-ɛ̂* 'jump_over.CP-3SG', *cǒɵt-ɛ̂* 'call.AP-2PL', *ṱ̤ɛ̀mm-ʌ̤́* 'cut.AP-1SG', *mâaað-ɛ̀* 'drink.CAUS-3SG', *jṳ́ɔ̤ɔ̤ɔ̤r-ɛ̀* 'jump_over.CP-2PL', *kwîr-kɛ̀* 'throw.CF-3PL', *ṯḛ́mm-ɛ̀* 'cut.APPL-2PL'. The only exception to this pattern is encountered in underived transitive forms with plural subjects, where the pattern L-L is found with short roots (e.g., *tɛ̀amm-ɛ̀* 'cut.TR-2PL'), but accounting for this exception is outside of the scope of this article.

Crucially, in all examples throughout this section, the falling tone is found only on modal vowels, while the high tone is found only on breathy vowels. In the next section, it will be demonstrated that this observation reflects an inviolable rule and that the high and falling tones are indeed in complementary distribution based on the phonation of the vowel.

[5] Whether a nominative case form is morphologically modified can be signaled through various clues: an overlong root vowel, a modified root vowel (see Table 2), or a mutated final consonant (in WN) always indicate the presence of non-concatenative morphemes; additionally, morphologically modified nouns tend to have segmentally suffixed oblique forms, while morphologically simple nouns derive oblique forms via non-concatenative morphology.

[6] See Section 5 on the nature of the non-segmental prefix *(µ)-*.

[7] The consonant (k) is present only after vowel-final roots, which are very rare. After consonant-final roots, representing an overwhelming majority, the genitive singular suffix has allomorph -ʌ̤.

[8] Which itself may be realized with a high or a falling allotone depending on the phonation of the vowel – see Section 4 for the details.

4 The phenomenon

On its own, the observation that the high level pitch only occurs on breathy vowels, while the falling pitch only occurs on modal vowels, does not prove the dependency of the tonal contour on voice quality, as it relies on a lack of evidence to the contrary. To convincingly establish this dependence, the phonation-based alternation between the high level and the falling tonal contours will be shown to occur in morphemes expected to have identical tonal values based on the morphological patterns of the language. This evidence is two-fold. First, inflected verbal stems will be shown to alternate between a high and a falling tone only when they show an alternation between a breathy and a modal vowel in their inflectional paradigm. In contrast, those verbal stems which maintain the same voice quality – breathy or modal – throughout the inflectional paradigm do not vary their tonal contour, manifesting either the high level or the falling tone in all inflected forms. Second, inflectional suffixes will be shown to alternate between having a high and a falling tone based on the phonation of the vowel of the suffix in those inflectional paradigms where they are expected to be associated with an H-tone.

The first part of the argument focuses on the alternation between H and HL in the stem, ignoring inflectional endings. Nuer relies heavily on the ablaut-like process of vowel quality modification in all aspects of its morphology. In particular, all inflectional processes – both in the nominal and verbal systems – involve alternating the stem vowel between two values which will be termed here 'basic' and 'modified.' The basic~modified pairings for all vowels are shown in Table 2. Arguments for treating one variant as basic and the other as modified are offered in Monich & Baerman (2019). The alternation shown in Table 2 is characteristic of inflectional morphology only. It is part of a larger phenomenon of vowel gradation that pervades the entire morphological system (see Reid 2019; Monich & Baerman 2016, 2019).

Table 2: Inflectional vowel quality modification

Basic	Modified
ɪ	ɪɛ
i̤	i̤e
e̤	e
ɛ	ɛa
ɛ̤	ɛ̤a̤
ʌ̤	a̤
a	a
ɔ	ɔa
ɔ̤	ɔ̤a̤
ɵ̤	ɵ
ʊ	ʊɔ
ṳ	ṳɔ̤

The distribution of basic and modified vowels in the inflected transitive paradigm is shown in Table 3. In the 2/3SG inflected forms, the stem manifests the 'basic' variant of the root vowel, while in all other forms, the stem shows the 'modified' variant of the vowel.

Table 3. The pattern of vowel quality modification in an inflected transitive paradigm

<table>
<tr><th></th><th>SG</th><th>PL</th></tr>
<tr><td>1</td><td></td><td rowspan="3">Modified</td></tr>
<tr><td>2</td><td rowspan="2">Basic</td></tr>
<tr><td>3</td></tr>
</table>

As evident in Table 2, inflectional modification of the root vowel mainly involves diphthongization with preservation of the phonation properties of the basic vowel: e.g., the vowel /i̤/ has an inflectional variant /i̤e̤/, the vowel /ɔ̤/ has an inflectional variant /ɔ̤a̤/, and so forth. This pattern is violated in three cases where the basic and the modified variants are both monophthongs: the vowel /ʌ̤/ has the modified variant /a̤/, while the breathy vowels /e̤/ and /ɵ̤/ have the corresponding modal variants /e/ and /ɵ/. In order to establish a robust correlation between tone and vowel phonation, the tonal patterns in inflected paradigms with constant root vowel phonation will be compared to those where the root vowel has a variable voice quality.

In the inflected paradigm of any given verb, all singular forms, on the one hand, and all plural forms, on the other, share the same length grade of the root vowel and the same tonal melody. The only exception is the alternation between high level and falling tones, which are found intermixed on the root or the suffix syllable in some verbs. This alternation of the high level and the falling tone will be shown here to correlate with vowel voice quality.

In what follows, singular forms of three verbs are compared. The three verbal roots all have a long root vowel; since the length of the root vowel primarily determines membership in a particular inflectional class, all three follow the same modification pattern in inflection. With all singular subjects, the long vowel of the verbal root lengthens to overlong, while the tone of the root may be high or falling. The quality of the stem vowel is basic in the 2/3SG form and modified in all other inflected forms, including the 1SG form. The verb *gɔ̤ɔ̤r* 'write.TR' represents verbs with root vowels that maintain breathy phonation throughout the inflectional paradigm (the basic vowel /ɔ̤/ has the modified variant /ɔ̤a̤/, both breathy); the verb *lɛɛl* 'do.TR' represents verbs which maintain modal phonation throughout the inflectional paradigm (the basic vowel /ɛ/ has the modified variant /ɛa/, both modal); the verb *gɵ̤ɵ̤r* 'want.TR' represents verbs which have breathy phonation in 2/3SG forms of the inflectional paradigm, but switch to modal phonation with all other persons (the basic vowel is breathy, i.e., /ɵ̤/, while the modified vowel is modal, i.e., /ɵ/).

In all inflected forms derived from roots with vowels /i̤, ṳ, ɔ̤, ʌ̤/,[9] the voice quality of the stem vowel is breathy throughout the inflectional paradigm, whether the stem vowel is basic or modified. With singular subjects, the stem is realized with high level tone in all three persons. The inflected paradigm of the verb *gɔ̤ɔ̤r* 'write.TR' is shown as an example in Table 4.

Table 4: The inflected paradigm of *gɔ̤ɔ̤r*- 'write.TR'

<table>
<tr><th></th><th>SG</th><th colspan="3">PL</th></tr>
<tr><td>1st</td><td>gɔ̤́a̤a̤a̤r-ʌ̤̀</td><td>gɔ̤̌a̤a̤r-kɔ̂ (EXCL)</td><td>gɔ̤̌a̤a̤r-nɛ̂ (INCL DU)</td><td>gɔ̤̌a̤a̤r-nɛ̂ (INCL PL)</td></tr>
<tr><td>2nd</td><td>gɔ̤́ɔ̤ɔ̤r-ì̤</td><td colspan="3">gɔ̤̌a̤a̤r-ɛ̂</td></tr>
<tr><td>3rd</td><td>gɔ̤́ɔ̤ɔ̤r-ɛ̀</td><td colspan="3">gɔ̤̌a̤a̤r-kɛ̂</td></tr>
</table>

The pitch tracks of two forms – the 1SG, which has the modified vowel, and the 2SG, which has the basic vowel – are shown in Figures 5 and 6. In both cases, the f0 rises slightly at the start of the vowel and then falls slightly towards its end. Throughout the vowel, the f0 remains relatively high – above 150Hz – and only deeps below this threshold in the low-toned suffix.

[9] The basic vowel /ɛ̤/ is marginal and arises only under specific morphophonological conditions in some nominal forms. It has not been found in any verbs.

gɔ̤́a̤a̤a̤r-ʌ̤̀ (the modified vowel in the root)
write.TR-1SG
'I write (something)'

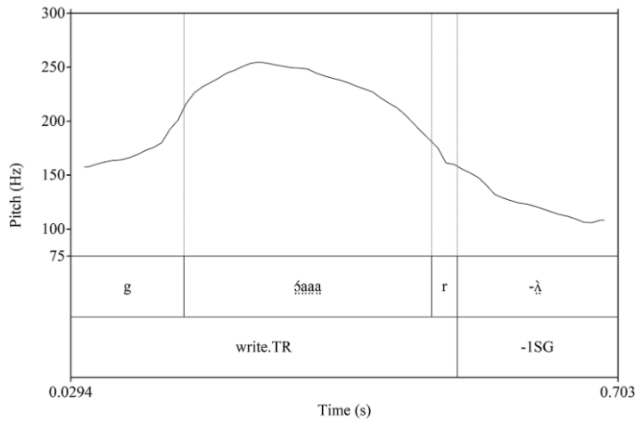

Figure 5: The High toneme in the 1SG form of the verb *gɔ̤ɔ̤r-* 'write.TR'

gɔ̤́ɔ̤ɔ̤r-ɪ̤̀ (the basic vowel in the root)
write.TR-2SG
'You write (something)'

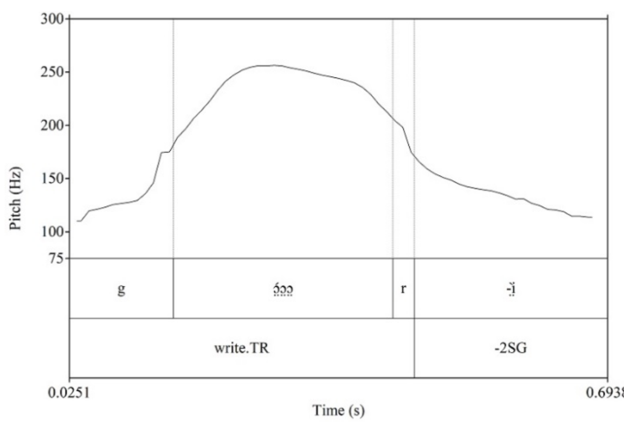

Figure 6: The High toneme in the 2SG form of the verb *gɔ̤ɔ̤r-* 'write.TR'

Conversely, in all inflected forms derived from roots with vowels /ɪ, ʊ, ɛ, ɔ, a/, the modal phonation of the vowel is maintained throughout the paradigm. With all singular subjects, the stem is pronounced with a falling tone. A sample paradigm of the verb *lɛɛl* 'do.TR' is shown in Table 5.

Table 5: The inflected paradigm of *lɛɛl-* 'do.TR'

	SG	PL		
1st	lɛ̂aaal-ʌ̤̀	lɛ̆aal-kɔ̂ (EXCL)	lɛ̆aal-nɛ̂ (INCL DU)	lɛ̆aal-nɛ̂ (INCL PL)
2nd	lɛ̂ɛɛl-ɪ̤̀	lɛ̆aal-ɛ̂		
3rd	lɛ̂ɛɛl-ɛ̀	lɛ̆aal-kɛ̂		

Comparing pitch tracks of the 1SG (modified root vowel) and the 2SG (basic root vowel) forms in Figures 7 and 8, we observe that in both forms, f0 starts at its peak right at the beginning of the vowel and falls immediately and sharply, reaching the level of the low-toned suffix by the end of the root syllable.

lɛ̂aaal-ʌ̤̀ (the modified vowel in the root)
do.TR -1SG
'I do (something)'

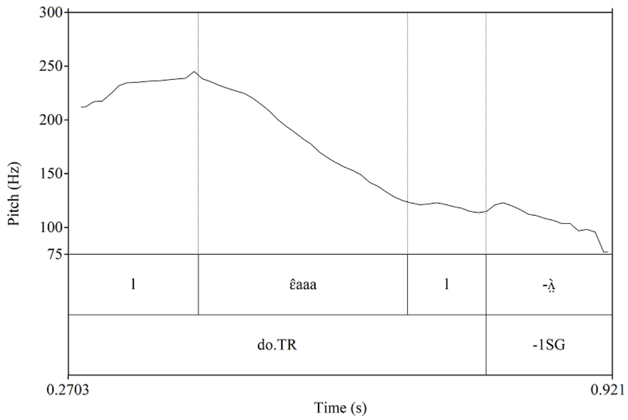

Figure 7: The High toneme in the 1SG form of the verb *lɛɛl-* 'do.TR'

lɛ̂ɛɛl-ì̤ (the basic vowel in the root)
do.TR-2SG
'You do (something)'

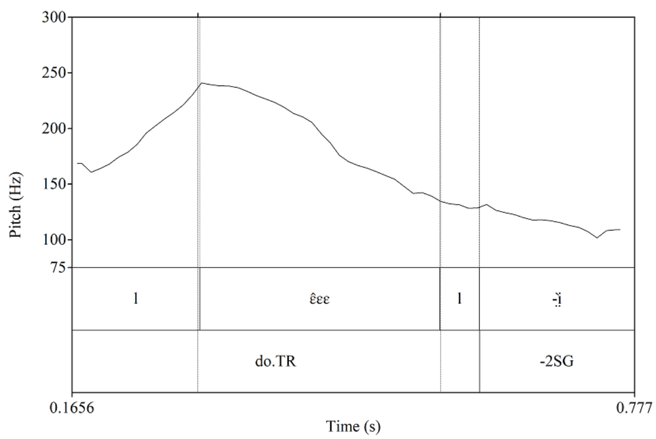

Figure 8: The High toneme in the 2SG form of the verb *lɛɛl-* 'do.TR'

The paradigms in Tables 4 and 5 demonstrate that the alternation between the high and the falling tone does not follow the distribution of modified vs. basic vowels in the stem.

Now let us turn to the verbs with vowels /e̤/ and /ɵ̤/ in the root. According to Table 2, inflectional modification of these two basic vowels amounts to a loss of breathy phonation. For example, the vowel of the verb *gɵ̤ɵ̤r-* 'want/search.TR' alternates between the breathy /ɵ̤/ and the modal /ɵ/, as shown in Table 6.

Table 6: The inflected paradigm of *g̤e̤e̤r-* 'want/search.TR'

	SG	PL		
1st	gêəər-À̤	gə̌ər-kɔ̂ (EXCL)	gə̌ər-nɛ̂ (INCL DU)	gə̌ər-nɛ̂ (INCL PL)
2nd	gé̤e̤e̤r-ì̤	gə̌ər-ɛ̂		
3rd	gé̤e̤e̤r-ɛ̀	gə̌ər-kɛ̂		

Importantly, the realization of the tonal contour in singular inflected forms of a verb like *g̤e̤e̤r-* follows the distribution of basic vs. modified vowel quality. The root vowel is realized with high level pitch in the 2/3SG forms, where the vowel is breathy, and with a fall in the 1SG form, where the vowel is modal. This difference in tonal contour is illustrated with pitch tracks in Figures 9 and 10.

gêəər-À̤ (the modified vowel in the root)
want.TR-1SG
'I want/look for (something)'

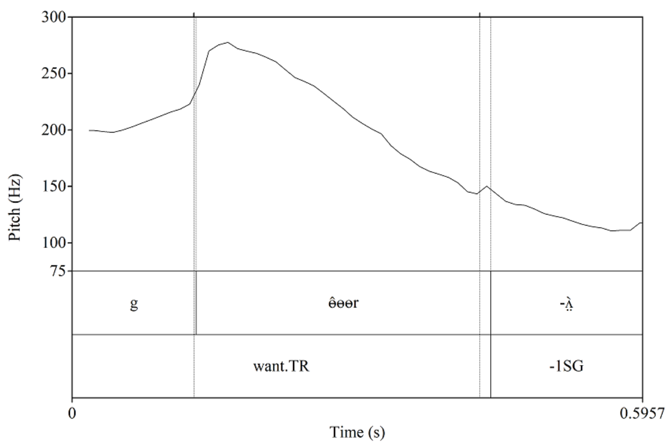

Figure 9: The High toneme in the 1SG form of the verb *g̤e̤e̤r-* 'want/search.TR'

gé̤e̤e̤r-ì̤ (the basic vowel in the root)
want.TR-2SG
'You want/look for (something)'

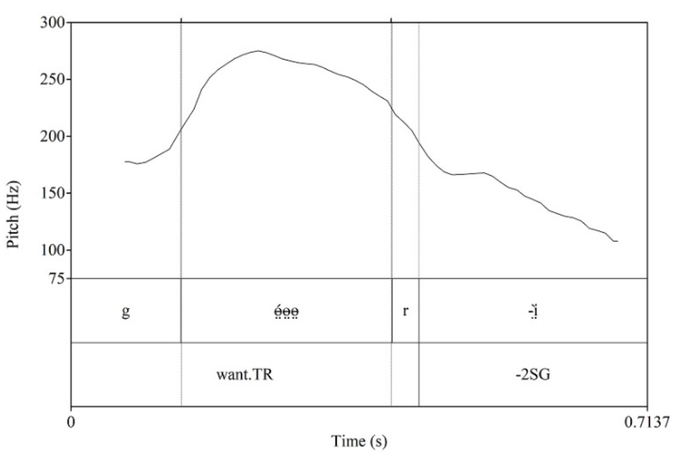

Figure 10: The High toneme in the 2SG form of the verb *g̤e̤e̤r-* 'want/search.TR'

The tonal contour of the 1SG form in Figure 9 is similar to that of both forms illustrated in Figures 5 and 6. The f0 peak of about 275Hz is found right at the start of the vowel and followed by a sharp and immediate fall to about 150Hz, the starting pitch level of the following low-toned suffix. On the other hand, the tonal contour of the 2SG form in Figure 10 shares many characteristics with the two tonal contours in Figures 7 and 8. The f0 rises slightly at the beginning of the vowel and drops slightly towards its end, but these fluctuations are minor: the tonal contour remains relatively high throughout the vowel, at a pitch level significantly above the following low-toned suffix.

As summarized in Table 7, the alternation between a high level and a falling tone in the stem of the three types of verbs considered here follows the distribution of breathy vs. modal vowels precisely.

Table 7: Distribution of falling and high tones in the verbal stem

	Stem with a breathy vowel (not /e̤/, /ɵ̤/)	Stem with a modal vowel	Stem with /e̤/, /ɵ̤/
1SG (modified)	gɔ̤́a̤a̤a̤r-ʌ̤̀	lɛ̂aaal-ʌ̤̀	gêɵɵr-ʌ̤̀
2SG (basic)	gɔ̤́ɔ̤ɔ̤r-ì̤	lɛ̂ɛɛl-ì̤	gé̤ɵ̤ɵ̤r-ì̤

We now turn attention to inflectional suffixes. As mentioned in the previous section, inflectional suffixes are not lexically specified for tone. The tone of the segmental suffix is variable and depends on the verbal stem to which it is affixed. Table 8 shows an example of a paradigm where the inflectional suffix has a low tone in both singular and plural forms.

Table 8: The inflected paradigm of *bṳ́l-* 'roast.APPL.TR'

	SG	PL		
1st	bṳ́ɔ̤ll-ʌ̤̀	bṳ́ɔ̤l-kɔ̀ (EXCL PL)	bṳ́ɔ̤l-nɛ̀ (INCL DUAL)	bṳ̌ɔ̤l-nɛ̂ (INCL PL)
2nd	bṳ́ll-ì̤	bṳ́ɔ̤ll-ɛ̀		
3rd	bṳ́ll-ɛ̀	bṳ́ɔ̤l-kɛ̀		

In paradigms with a non-low tonal contour on the inflectional suffix, exemplified in Table 9, the suffix has a high level tone in 1/2SG forms and a falling tone in all other forms.

Table 9: The inflected paradigm of *bṳ̀ṳl-* 'roast.AP(Antipassive)'

	SG	PL		
1st	bṳ̀ɔ̤ɔ̤l-ʌ̤́	bṳ̀ɔ̤ɔ̤l-kɔ̂ (EXCL)	bṳ̀ɔ̤ɔ̤l-nɛ̂ (INCL DUAL)	bṳ̌ɔ̤ɔ̤l-nɛ̂ (INCL PL)
2nd	bṳ̀ṳl-í̤	bṳ̀ɔ̤ɔ̤l-ɛ̂		
3rd	bṳ̀ṳl-ɛ̂	bṳ̀ṳl-kɛ̂		

Pitch tracks comparing the high tone on the 2SG suffix with the falling tone on the 3SG suffix are shown in Figure 11 and 12 correspondingly. Again, we see the same general shape of the two tones: in Figure 11, f0 is slightly rising at the beginning of the vowel and slightly falling towards its end, but these fluctuations take place within a limited frequency range; in Figure 12, on the other hand, f0 peaks right at the start of the vowel and drops immediately and precipitously.

bṳ̀ṳl-í̤
roast.AP-2SG
'You roast.'

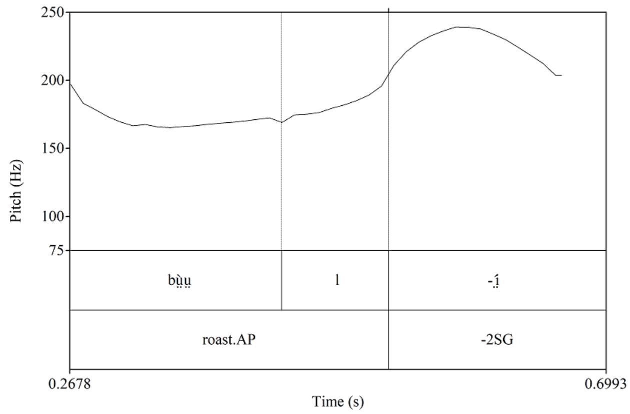

Figure 11: The High toneme on the 2SG suffix in the inflected form of the verb *bṳ̀ṳl-* 'roast.AP'

bṳ̀ṳl-ɛ̂
roast.AP-3SG
'He roasts.'

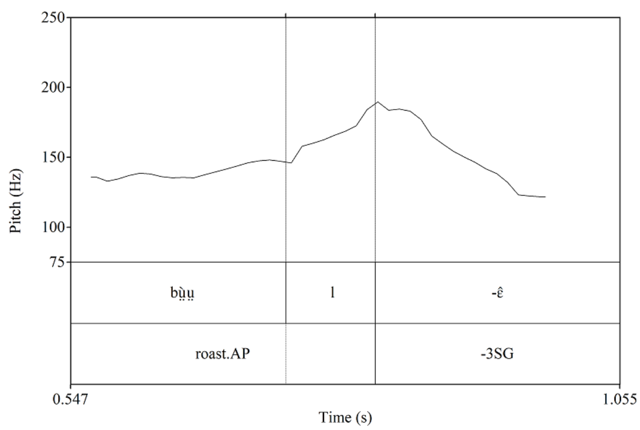

Figure 12: The High toneme on the 3SG suffix in the inflected form of the verb *bṳ̀ṳl-* 'roast.AP'

Based on Table 9, we observe that the distribution of high level vs. falling tone in inflectional suffixes follows the phonation of the vowel in the suffix: the 1/2SG inflectional suffixes contain breathy vowels and are associated with a high level tone; in contrast, all other inflectional suffixes contain modal vowels and are associated with a falling tone. Therefore, each personal suffix, depending on the base to which it is affixed, may have one of two values: 1/2SG inflectional suffixes vary between having a low and a high level tone, while all other inflectional suffixes vary between having a low and a falling tone.

The same relationship between phonation and tone is evident in the nominal system: stems containing a modal vowel may be associated with a falling tonal contour and never with a high level tone (i.e., *rɔ̂ɔɔm* 'sheep.PL.NOM', *tôŋ-nì* 'egg.PL-OBL', etc.); stems with a breathy vowel may be associated with a high level tone but never a falling tone (i.e., *pɔ̤́a̤a̤r* 'cloud.PL.NOM', *ŋwá̤g-nì* 'neck.PL-OBL', etc.). Again, especially convincing are the wordforms with similar morphological make-up, which only differ in vowel phonation. For example, all deverbal agentive nouns have identical morphophonological properties: they have an overlong stem vowel in all inflected forms; in the Nom Sg form, they have a breathy vowel of the basic set in Table 2 (i.e., /i̤, ṳ, e̤, ɵ̤, ɔ̤, ʌ̤/), while in the Nom Pl form, they have a modified version of these same vowels; the Gen Sg form is marked with the segmental suffix-*(k)ʌ̤* but otherwise is identical to the Nom Sg form. A few examples are shown in Table 10 below.

Table 10: Agentive deverbal nominalizations

Verbal root	**Agentive noun**			
	NOM SG	**GEN SG**	**NOM PL**	**Gloss**
cɔɔl- 'call'	cɵ̤́ɵ̤ɵ̤l	cɵ̤́ɵ̤ɵ̤l-ʌ̤̀	cɵ̂ɵɵl	'caller'
nɛɛn- 'see'	né̤e̤e̤n	né̤e̤e̤n-ʌ̤̀	nêeen	'witness'
kɪɪt- 'sing'	kí̤i̤i̤t	kí̤i̤i̤t-ʌ̤̀	kí̤e̤e̤e̤t	'singer'
dʊʊl- 'collect'	dṳ́ṳṳl	dṳ́ṳṳl-ʌ̤̀	dṳ́ɔ̤ɔ̤ɔ̤l	'collector'
t̪aal- 'cook'	t̪ʌ̤́ʌ̤ʌ̤l	t̪ʌ̤́ʌ̤ʌ̤l-ʌ̤̀	t̪á̤a̤a̤l	'cook'
gɔ̤ɔr 'write'	gɔ̤́ɔ̤ɔ̤r	gɔ̤́ɔ̤ɔ̤r-ʌ̤̀	gɔ̤́a̤a̤a̤r	'writer'

As Table 10 shows, those aspects of a phonological structure that are subject to morphological modification in Nuer (i.e., vowel length, vowel quality (basic vs. modified), suffixation, and tone) are identical in all deverbal agentive nouns. The only variable property is the tonal contour in Nom Pl forms, which alternates between high level and falling depending on whether the modified version of the stem vowel is breathy or modal. The above-cited data from verbal and nominal paradigms suggests that syllables that must be presumed to be identical in underlying tonal specifications are realized with a falling pitch if they contain a modal vowel and with a high pitch if they contain a breathy vowel.

The following section examines the underlying tonal structures behind the H vs. HL alternation, offering evidence that both H and HL sequences can be generated through morphological operations. In other words, it argues for the underlying four-toneme contrast with the subsequent surface merger of the two tonal melodies H and HL as a single toneme.

5 The underlying tonal oppositions

Monich (2020) offered empirical evidence that a Nuer syllable can be associated with one of the following three tonemes – High, Low, and Rising – but avoided making claims about their underlying makeup. There are only three contrastive tonemes on the surface, as the high and falling tones are in perfect complementary distribution. In this article, however, the tonal structures are considered at a deeper level to determine which allotone is underlying: Is there only an underlying toneme H with an allotone HL over modal vowels? Or only an underlying toneme HL with an allotone H over breathy vowels? Alternatively, are there two underlying tonemes, H and HL, which neutralize on the surface? Based on the available information so far, the last possibility appears to be the correct one. To put it differently, it seems likely that the interaction of tone and phonation in Nuer involves two phonological processes: one converting H to HL in modal vowels and another converting HL to H in breathy vowels. Some of the facts motivating such an analysis are laid out below.

From the earlier discussion of the verbal system, we can infer that there exist at least some underlying H-tones and that they are realized as surface HL over modal vowels. Recall that with a single exception, the tonal properties of inflectional suffixes are assigned with reference to the tone of the stem: after a high or a falling tone in the stem, the tone of the suffix is low; after a low or a rising tone in the stem, the tone of the suffix is level high over breathy vowels and falling over modal vowels. This pattern is most elegantly explained on the assumption that inflectional suffixes are assigned a tone polar to (the first autosegment of) the stem: an L after H/HL and an H after L/LH. An H assigned to the suffix with a modal vowel is then implemented as a fall (HL). An analysis positing the underlying alternation of the suffixal tone between L and HL would be incompatible with a polar tone analysis. It would be difficult, even impossible, to account for the tonal patterns observed in the inflectional suffixes under such an approach. Therefore, we must conclude that underlying H-tones are generated at least in some contexts (e.g., in suffixes) and that they are converted to HL over modal vowels by a high-level phonetic rule.

Additionally, there is evidence that the process applies in the other direction to realize the underlying HL contour as H over breathy vowels. In order to demonstrate that HL tonal melodies can be generated underlyingly and modified based on vowel phonation, it is not necessary to delve deeper into Nuer's morphotonology. There exists a phenomenon that illustrates the generation of complex tonal melodies more convincingly, and it is described below.

5.1 Tonal effects of ‘floating’ prefixes

There are no vowel-initial native words in Nuer. All verbal and nominal forms are exclusively consonant-initial. However, some nouns contain a non-segmental prefix that manifests itself only in the position after another word by lengthening its final vowel (if it is vowel-final). Considering this lengthening effect, the prefix may be analyzed as consisting of a floating mora and represented symbolically as *(μ)-*. The segmental cognates of this prefix are still attested in other closely related West Nilotic languages, notably in Dinka, where the toneless prefix *a-* is common and even seemingly productive in deverbal nouns (Remijsen 2008). For example, the Nuer nouns *(μ)-cwɛ̀ak* ‘twin’, *(μ)-cɔ̤̌k* ‘ant’*, (μ)-gṳ̌ṳṳk* ‘dove’ are consonant-initial in isolation and following consonant-final words but are all associated with the lengthening of the preceding word’s final vowel. The Dinka cognates of these Nuer words all begin with the toneless prefix *a-*: *acwěeek* twin’, *acṳ̀ṳṳk* ‘ant’, *agṳ̌ṳṳk* ‘dove’.[10] The floating prefix in Nuer might still be productive as it appears in many deverbal instruments, e.g. *(μ)-jḛ́ḛḛc* ‘broom’(<*jɛɛc-* ‘sweep’), *(μ)-pḭ̌c* ‘stirring stick’ (< *pḭḭc-* ‘stir’), *(μ)-bʌ̤̌ʌ̤ʌ̤r* ‘arrow’ (< *bʌ̤ʌ̤r-* ‘shoot’), etc.[11,12]

Crucially, the presence of the floating prefixal mora is of consequence not only for the duration of the preceding vowel but also for its tonal contour. The Figures 13-16 below compare the realization of the underlyingly low-toned vocalic inflectional suffix -ʌ̤ in the environment of two minimally different nouns: *lɛ̂p* ‘tongue’ and *(μ)-lɛ̂k* ‘pestle’. As the Figures 13 and 14 show, the verbal suffix is short and low-toned before both singular and plural forms of the noun *lɛ̂p*; in contrast, before singular and plural forms of the noun *(μ)-lɛ̂k*, shown in Figures 15 and 16, the verbal suffix is significantly longer and pronounced with a rising tone. It should be noted that the rising pitch over the verbal suffix in Figures 15 and 16 cannot be due to interpolation between a low and a high tone. Since Nuer has both the Low and the Rising tonemes, low tones are executed precisely before high tones, without any significant increase in f0 throughout the vowel, and thus are kept distinct from rising tones.

[10] The Dinka data comes from B. Remijsen’s database (p.c.).

[11] In some Western Nuer dialects, the presence of the prefix is associated with the prenasalization of the following stop, *tîɛɛɛm-ʌ̤̌* ***m****pɔ̤̀a̤r* ‘I remember a/the cloud’.

[12] See Monich (2021, 2023) for another morpheme that manifests identical phonological behaviour: a linker that appears under certain phonological conditions between two members of an adnominal possessive construction.

tîɛɛɛm-ʌ̤̀ lɛ̂p
remember.TR-1SG tongue.SG.NOM
'I remember a tongue.'

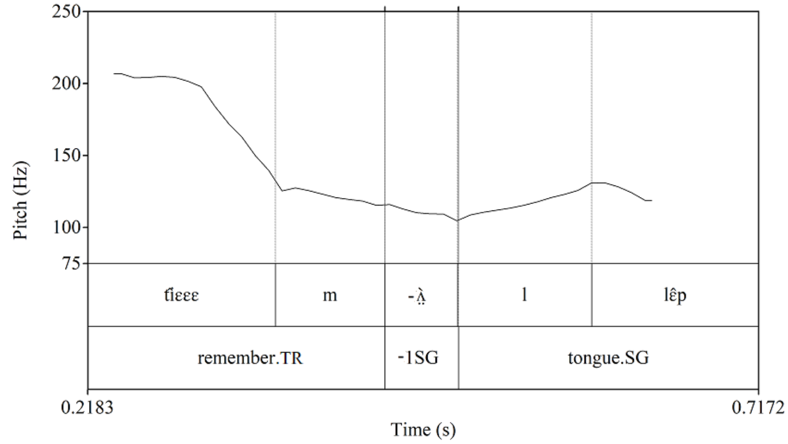

Figure 13: Realization of the L-toned 1SG suffix before the unprefixed noun *lɛ̂p* 'tongue.SG'

tîɛɛɛm-ʌ̤̀ lêeep
remember.TR-1SG tongue.PL.NOM
'I remember tongues.'

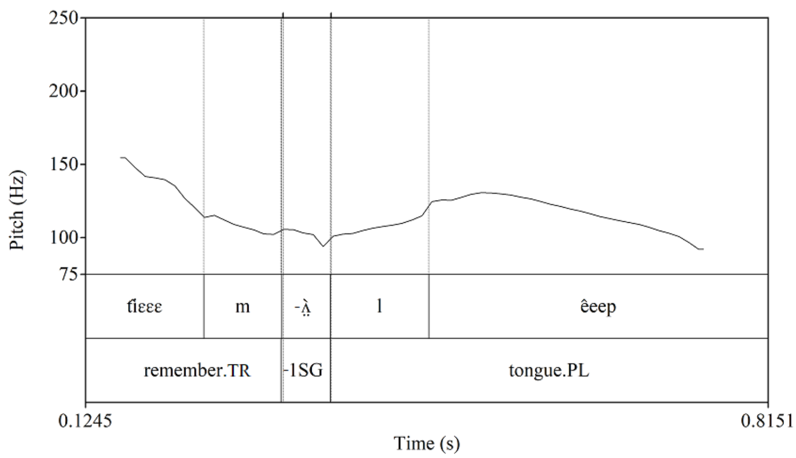

Figure 14: Realization of the L-toned 1SG suffix before the unprefixed noun *lêeep* 'tongue. PL'.

/tíɛɛɛm-ʌ̤̀ (µ)-lɛ́k/ = tîɛɛɛm-ʌ̤̌ʌ̤ lɛ̂k
remember.TR-1SG pestle.SG.NOM
'I remember a pestle.'

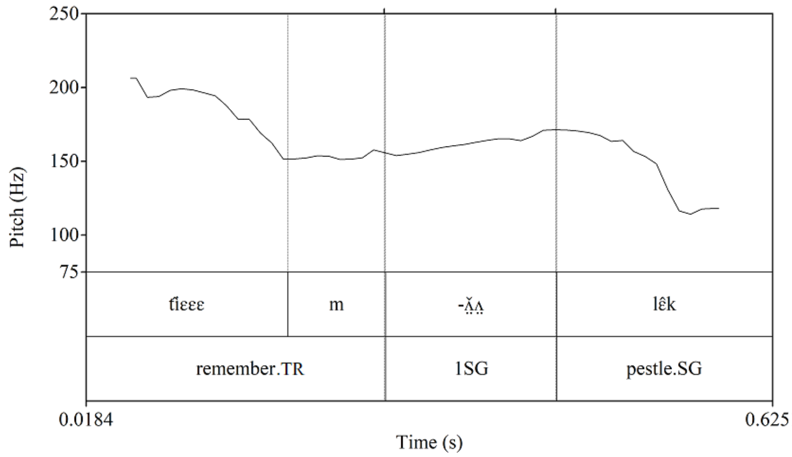

Figure 15: Realization of the L-toned 1SG suffix before the prefixed noun *(µ)lɛ̂k* 'pestle.SG'

/tíɛɛɛm-ʌ̤̀ (µ)-léeek/ = tîɛɛɛm-ʌ̤̌ʌ̤ lêeek
remember.TR-1SG pestle.PL.NOM
'I remember pestles.'

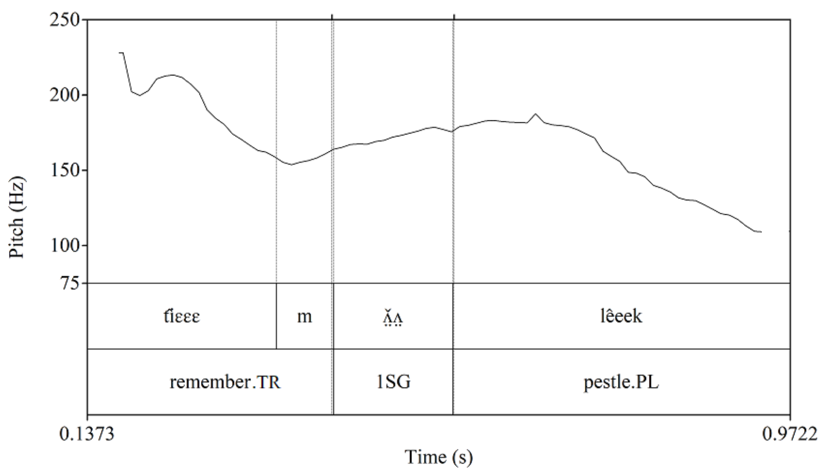

Figure 16: Realization of the L-toned 1SG suffix before the prefixed noun *(µ)lêeek* 'pestle.PL'

The tonal effects associated with the moraic prefix were first noted in Crazzolara (1933), who does not make a diachronic connection to vocalic prefixes in other WN languages but notes that some Nuer nouns trigger lengthening of the preceding vowel and what he calls a "tonal shift": placing a polar tone after the tone of the suffix. Specifically, he observes that when the prefixed nouns follow a vowel-final suffix or a vowel-final preposition, the preceding vowel "will be doubled and the second of these vowels will take up the special tone required, high if the preceding is low, low if the preceding is high" (p.24). Moreover, as Crazzolara notes, sometimes the effect of the prefix is purely tonal: When following a low-toned consonant-final verb, the floating tone does not interfere with the quantity of the vowel but does interfere with the tone of the verb form.[13] We largely confirm these findings, although we elaborate on them by noting that, in the dialects considered by us, phonation interfered with the generalization made in Crazzolara.[14]

When the final vowel of the preceding word has a low tone, the added floating mora is assigned a polar – that is, high – tone. The combination of L and H yields a rising tone LH which is realized as such before the following noun associated with a High toneme. To the examples illustrating this in Figures 15 and 16, we add another pitch track in Figure 17.

/tíɛɛɛm-ʌ̤̀	(µ)-t̪í̤i̤i̤k /	=	tîɛɛɛm-ʌ̤̌ʌ̤ t̪í̤i̤i̤k
remember.TR-1SG	door.SG.NOM		

‘I remember the door.’

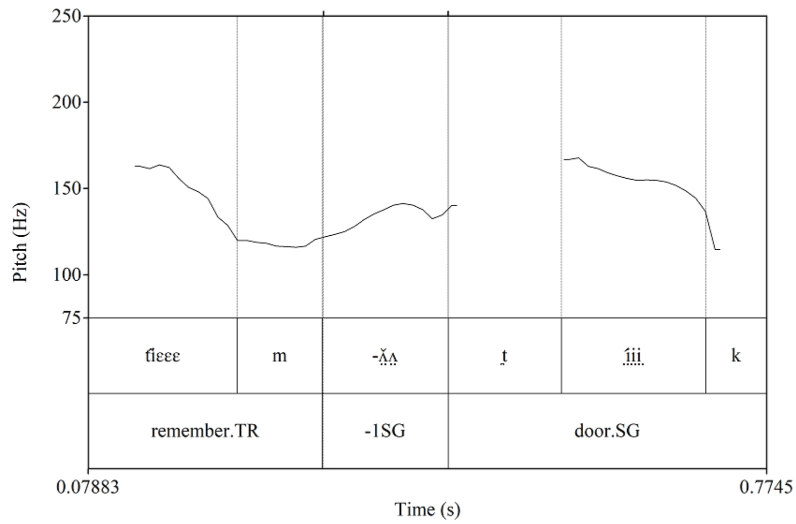

Figure 17: Realization of the L-toned 1SG suffix before the prefixed noun *(µ)t̪í̤i̤i̤k* ‘door.SG’

In a few contexts, particularly before a noun associated with a Low toneme, the rising tone, which emerges through a combination of the low suffixal tone and the polar tone of the moraic prefix, is realized with a mid allotone of the Rising toneme, as illustrated in Figure 18.[15] The dimoraic sequence is usually shortened in this case. The mid tone is an allotone of a Rising toneme and *always* indicates the underlying LH tonal contour. In most contexts, whether the mid or rising allotone of the Rising toneme is chosen is a matter of free variation; however, some tonal settings demand one or the other allotone. In particular, the

[13] Crazzolara reports that the tone of the imperative form changes with the addition of the prefix if it is low-toned but not if it is high-toned. In our observation, underived transitive 2SG imperative forms (the only imperative forms which are unsuffixed) are never high-toned: 2SG imperative forms of Class I (verbs with a short root vowel) are low-toned and those of Class II (verbs with a long root vowel) have a rising tone. Since Crazzolara does not approach the tonemic inventory of Nuer in a systematic way and mainly relies on his impressions of relative pitch level, he likely identifies 2SG imperatives of Class II verbs as being high-toned.

[14] Whether Crazzolara was working with speakers of dialects that did not display neutralization of H and HL based on phonation or whether he did not notice it, we cannot say. It is potentially relevant that Crazzolara conducted his work among the Nuer speakers almost a century ago.

[15] Note that the rising tone emerges as a combination of L and H, which are contributed by two separate sources, offering support to the analysis of the rising tone as the basic toneme with a mid allotone. Analyses such as Reid (2019), where the Mid allotone is posited as the default, must make a non-economic assumption that there exists an underlying Mid toneme that is realized with a rising allotone in specific contexts and also a separate rising tone which emerges as a result of L + H combinations.

rising tone is obligatorily converted to mid between high and low tones, i.e., the tonal sequence H-LH-L is realized as H-M-L.

/cṳ́ɔ̤ɔ̤ɔ̤l-ʌ̤̀	(µ)-bì̤i̤i̤j/	= cṳ́ɔ̤ɔ̤ɔ̤l-ʌ̤̄ʌ̤ bì̤i̤i̤j
blacken.TR-1SG	cloth.SG.NOM	
‘I blacken the cloth.’		

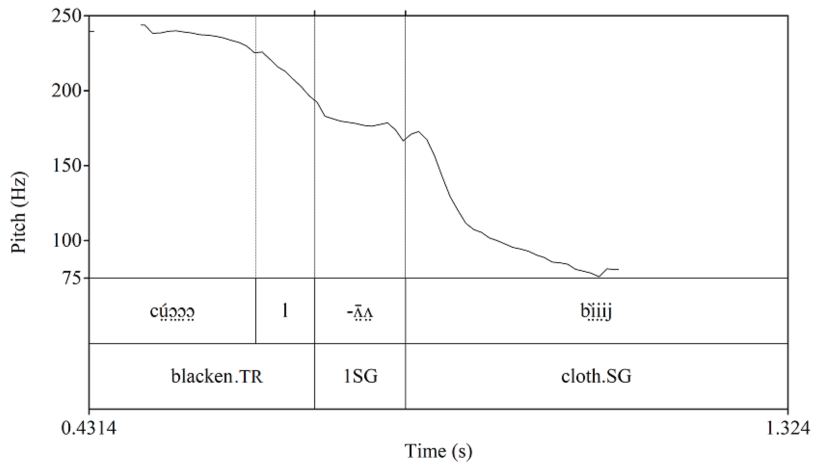

Figure 18. Realization of the L-toned suffix before the prefixed noun *(µ)bì̤i̤i̤j* ‘cloth.SG’

After a high-toned suffix, the floating mora contributed by the prefix can be assumed to be assigned a low tone in the underlying representation. This assumption is based on both Crazzolara’s report and our general observations of how tonal values are assigned to underlyingly toneless segments in Nuer. The combination of the H of the suffix and the following polar L of the prefix yields an HL sequence over the lengthened vowel of the suffix. However, there are no surface changes to the tonal contour in suffixes incorporating the floating prefix. As illustrated in Figures 19-22 below, the vowel has high level pitch if it is breathy and a falling contour if it is modal whether or not it incorporates the prefix. In parallel to the realization of the floating quantity after a low-toned suffix, the lengthening of the suffixal vowel is much more perceptible if it has a contoured tone than a level one. In other words, a lengthened suffix associated with the LH or HL tonal melody is perceptibly longer than a lengthened suffix which surfaces with the contextual allotones M and H of these two tones correspondingly.

/lĕpp-ɛ̂ (µ)-t̪i̤i̤i̤k/ = lĕb-ɛ̂ɛ t̪í̤i̤i̤k
open.TR-3SG door.SG.NOM
'He opens the door.'

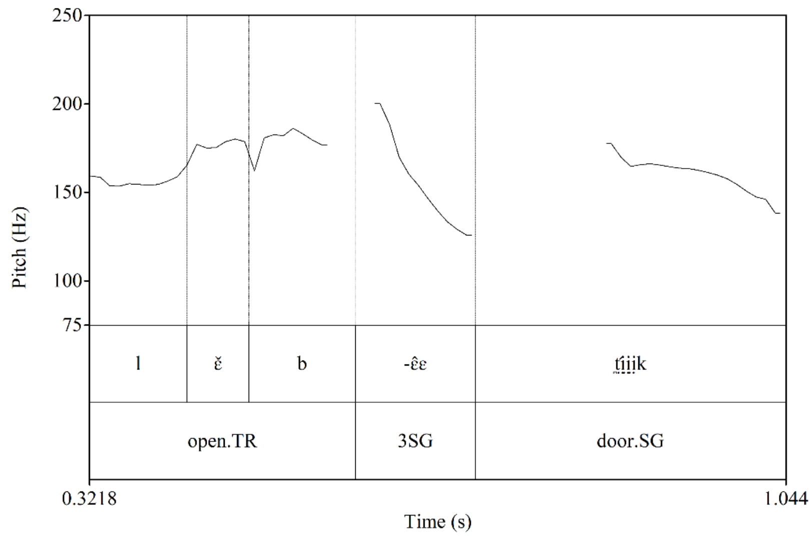

Figure 19: Realization of the H-toned 3SG suffix before the prefixed noun *(µ)t̪i̤i̤i̤k* 'door.SG'

/lĕpp-ɛ̂ dwĕ̤e̤l/ = lĕb-ɛ̂ dwè̤l
open.TR-3SG house.SG.NOM
'He opens a house'

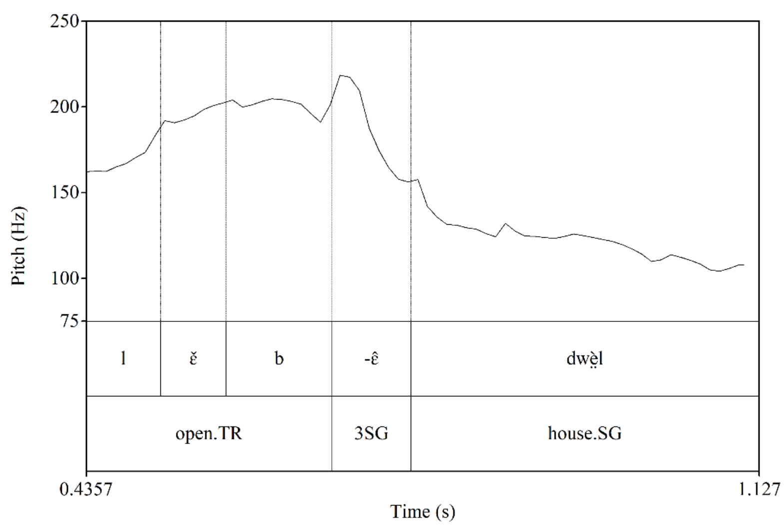

Figure 20: Realization of the H-toned 3SG suffix before the unprefixed noun *dwĕ̤e̤l* 'house.SG'

/lɛ̌app-ʌ̤́ (µ)-t̪í̤i̤k/ = lɛ̄ab-ʌ̤́ʌ̤ t̪í̤i̤k
open.TR-1SG door.SG.NOM
'I open the door'

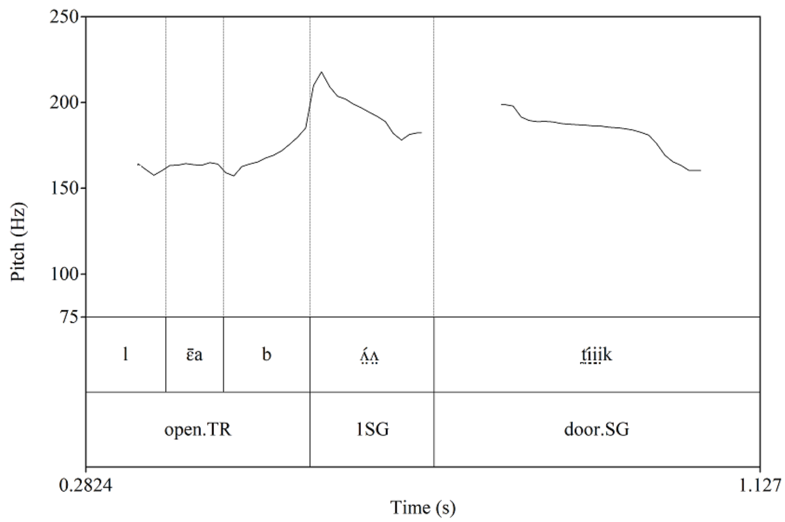

Figure 21: Realization of the H-toned 1SG suffix before the prefixed noun *(µ)t̪í̤i̤k* 'door.SG'

/lɛ̌app-ʌ̤́ dwɛ̤̌ɛ̤l/ = lɛ̌ab-ʌ̤́ dwɛ̤̀l
open.TR-1SG house.SG
'I open the house.'

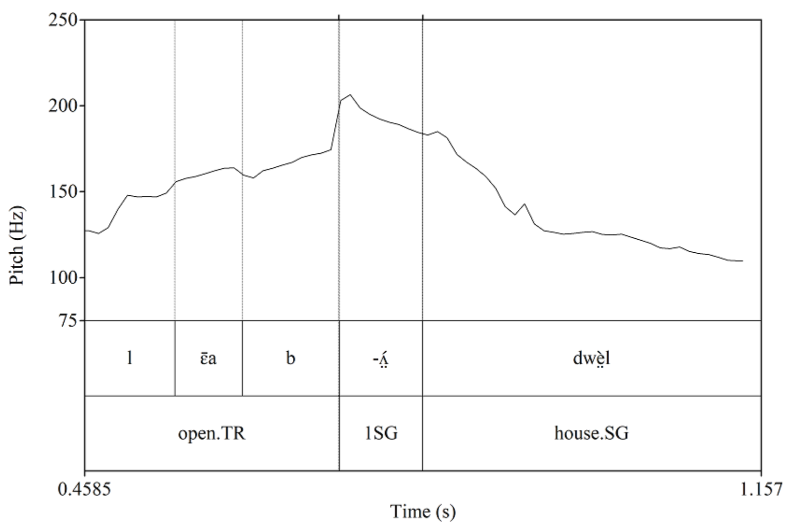

Figure 22: Realization of the H-toned 1SG suffix before the unprefixed noun *dwɛ̤̌ɛ̤l* 'house.SG'

When following a consonant-final form, prefixed nouns have no effect on the vowel quality of the preceding syllable but trigger the same effects in its tonal contour: If the preceding word is low-toned, an H-tone is added to the L, yielding a Rising toneme. Figures 23 and 24 compare the realization of the same low-toned verb *kɛ̤̀t* before a prefixed low-toned subject (Figure 23) and a non-prefixed low-toned subject (Figure 24). As Figure 23 shows, before the prefixed noun *(µ)-kṳ̀n* the verb *kɛ̤̀t* is realized with a mid allotone of the Rising toneme.

/kè̤t	(µ)-kṳ̀n	jě̤e̤e̤r/	=	kē̤t kṳ̀n jē̤e̤e̤r
swim.AP.NSF	rat.SG.NOM	river.SG.LOC		

'The rat swims in the river.'

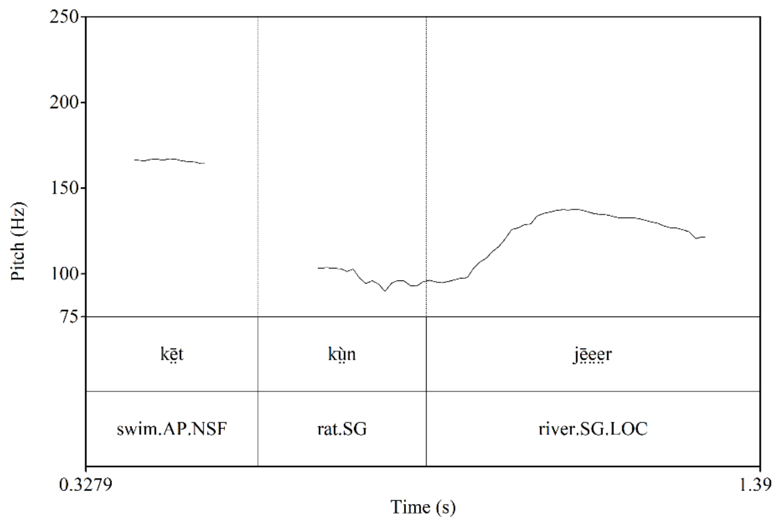

Figure 23: Realization of an L-toned verb before a prefixed subject *(µ)kṳ̀n* 'rat.SG'

kè̤t	rɔ̀aaam	jē̤e̤e̤r
swim.AP.NSF	sheep.SG.NOM	river.SG.LOC

'The sheep swims in the river.'

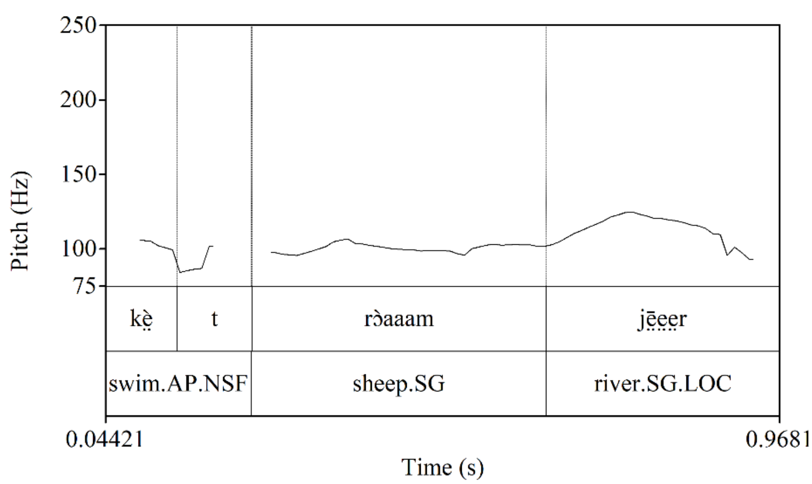

Figure 24: Realization of an L-toned verb before an unprefixed subject *rɔ̀aaam* 'sheep.SG'

After a verbal form associated with a High toneme, the prefix has no effect, as shown in Figures 25 and 26, which compares the realization of the same high-toned verb *kɛ̂t* before a subject with and without the floating prefix. Since the verb *kɛ̂t* has a modal root vowel, it is pronounced with a falling pitch whether a prefixed noun follows it or not. Similarly, a verb with a breathy vowel in the root is pronounced with a level high pitch in analogous environments (relevant pitch tracks are not shown for space considerations).

/kɛ́t	(µ)-kṳ̀n	jḛ́ḛr/	=	kɛ̂t kṳ̀n jḛ́ḛr
swim.TR.NSF	rat.SG.NOM	river.SG.NOM		

'The rat swims (across) the river.'

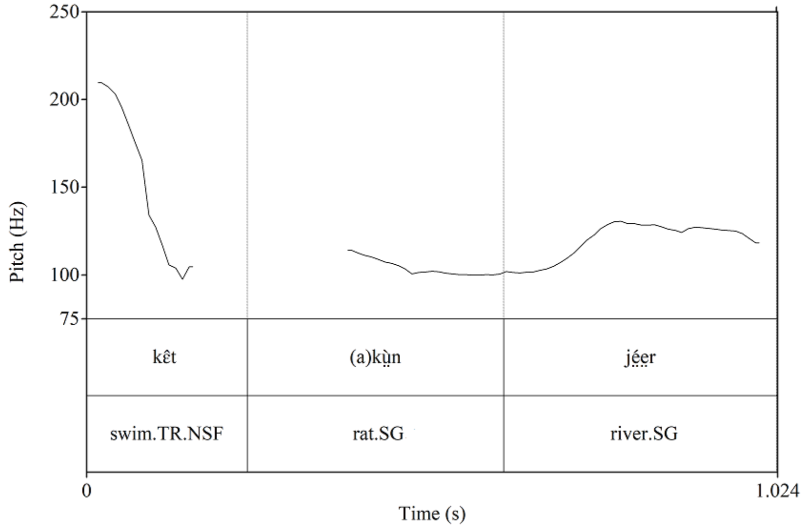

Figure 25: Realization of an H-toned verb before a prefixed subject *(µ)kṳ̀n* 'rat.SG'

kɛ̂t	rɔ̀aaam	jḛ́ḛr
swim.TR.NSF	sheep.SG.NOM	river.SG.NOM

'The sheep swims (across) the river.'

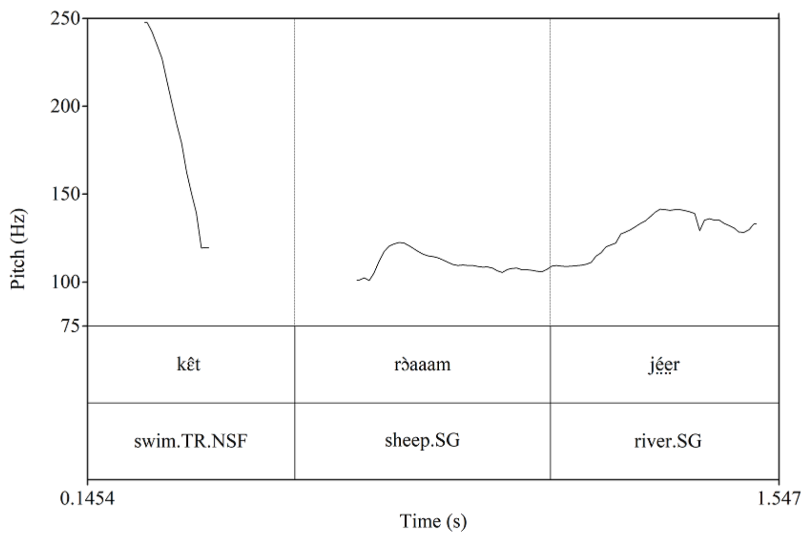

Figure 26: Realization of an H-toned verb before an unprefixed subject *rɔ̀aaam* 'sheep.SG'

To summarize, the behavior of non-segmental prefixes demonstrates that complex tonal melodies may be generated in Nuer by combining tonal materials from heterogeneous sources. Both LH and HL tonal sequences arise when the prefix *(µ)-* is assigned a tone that is polar to the tone of the preceding syllable. However, the tonal value the prefix contributes is perceptible only in combination with an L-toned root or prefix as part of the LH contour (or its mid allotone). When the polar tone is added to a syllable associated with an H tone, the resulting melody HL is realized as H or HL based on the phonation of the vowel. The presence of the prefix *(µ)-* is still perceptible in this case after vowel-final words due to the lengthening effect that it triggers. After high-toned consonant-final words, where vowel lengthening is not possible, the presence of the suffix is entirely obscured due to the neutralization of the contrast between H and HL tonal contours.

We, therefore, have evidence that the underlying tonal structures generate both H and HL tonal contours: when a suffix is assigned an H-tone, it is realized as an HL if the suffixal vowel is modal; if an H-toned suffix is lengthened due to the presence of a floating prefix in the following word, an underlying HL-melody is generated, but it is realized as H if the vowel of the suffix is breathy. Consequently, it is claimed here that there are two rules at work instead of one, contrary to Monich (2020): the first rule converts an H associated with a modal vowel to HL; the second rule converts an HL contour associated with a breathy vowel to H.

5.2 How many tonemes underlyingly?

The analysis presented here raises the following question: if the underlying tonal structures generate both H and HL, but the two tonemes are fully collapsed and indistinguishable on the surface, how can Nuer speakers arrive at the underlying structures? Would such a system not be unlearnable?

The answer to this question seems to be that Nuer speakers can infer the distribution of H and HL in the underlying structures because it fully parallels that of L and LH. In its turn, the distribution of L and LH tones is subject to significant constraints, briefly described below. The following description is not meant to be a complete analysis but rather a suggestion of how the Nuer tonal system might be set up based on a few observed patterns.

Examining the Nuer morphology, it becomes clear that the low and the rising tones pattern together in many morphophonological processes. For example, they both condition the realization of the polar tone as H in suffixes. In adnominal possessive constructions, alienably possessed nouns associated with low and rising tones pattern together in retaining their tonal properties, while those associated with high and falling tones change their tone to low (Monich 2021, 2023).[16] Most tellingly, low and rising tones are in complementary distribution in most morphological contexts: the low tone is found specifically on short vowels, which are followed by a mutated (i.e., devoiced in EN and devoiced + spirantized in WN) consonant, while the rising tone is found on long or overlong vowels, and also on short vowels followed by a non-mutated consonant. For example, multiplicative stems with short vowels (derived from roots with long vowels via shortening) have a low tone (e.g., EN *pwɔ̤̀t* 'strike (the drum).MULT', WN *pwɔ̤̀r̥* < *pwɔ̤̌ɔ̤t*), while multiplicative stems with overlong vowels (derived from roots with short vowels via lengthening) have a rising tone (e.g., EN *kø̤̌ø̤ø̤k* 'buy.MULT', WN *kø̤̌ø̤ø̤ɣ* < *kɔk*). Likewise, in plural forms of underived transitive stems, long vowels are associated with a rising tone, while short vowels are associated with a low tone: EN *pwɔ̤̌ɔ̤t-ɛ̂*, WN *pwɔ̤̌ɔ̤r̥-ɛ̂* 'shoot.TR-2PL' vs. EN *kɔ̀akk-ɛ̀, WN kɔ̀ax-ɛ̀* 'buy.TR-2PL'. We find the same pattern with the antipassives: the antipassive stems with short vowels have a low tone, but the antipassive stems with long vowels have a rising tone: EN *pwɔ̤̌ɔ̤t, WN pwɔ̤̌ɔ̤r̥* 'shoot.AP' vs. EN *kø̤̀k, WN kø̤̀x* 'buy.AP'. In all these structures, the low tone alternating with a rising tone is found specifically on short vowels, followed by a mutated consonant.[17] Additionally, one may observe that in morphologically underived

[16] For example, the noun *tṳ́ŋ* 'horn' changes its tone to low when alienably possessed – *tṳ̀ŋŋ-dá̤* 'my (animal) horn' (cf. *tṳ́ŋŋ-dá̤* 'my (own) horn') – and so does the noun *lɔ̂ɔc* 'heart' as in *lɔ̀ɔj-dá̤* 'my (animal) heart' (cf. *lɔ̂ɔj-dá̤* 'my (own) heart'). In contrast, the tone of both the low-toned noun *(μ)kø̤̀ø̤m* 'shinbone' and of the noun *wănn* 'eye' remains the same under alienable construal: *(μ)-kø̤̀ø̤m-dá̤* (both 'my own shinbone' and 'an animal shinbone in my possession') and *wănn-dá̤* (both 'my own eye' and 'an animal eye in my possession').

[17] Presence of a mutated consonant is more conspicuous in Western Nuer, where the final mutated consonant is both devoiced and spirantized. In Eastern Nuer varieties, which do not have the process of spirantization, the consonantal mutation is conspicuous only in suffixed forms, where intervocalic voicing of the stem-final consonant, which normally applies before vowel-initial suffixes, is blocked in mutated contexts (e.g., EN *kø̤̀kk-ɛ̂* 'buy.AP-3SG' corresponding to EN *kø̤̀x-ɛ̂*).

forms, one finds the rising tone only, never low – a fact that is expected based on this distribution since the final consonant of the root is inherently non-mutated in morphologically basic forms.

To account for the distribution of low vs. rising tones, we can propose that coda consonants count as TBUs (moras) unless they are mutated, i.e., unless they are specified as [-voice] in the course of the morphological derivation. The Rising tone is realized as LH in all environments where the syllable contains minimally two TBUs: that is, in syllables with long or overlong vowels or in syllables with short vowels + a non-mutated coda. The Rising tone is realized as L in syllables with a single TBU: a short vowel followed by a mutated coda.

That is not to say that minimal pairs showing a contrast between the Low and the Rising tonemes do not exist: they do, e.g., *jṳ̀ṳṳr* ‘jump_over.CP’ vs. *jṳ̌ṳṳr* ‘jump_over.MULT’. However, the Low toneme in such pairs is always provided via templatic morphology, i.e., morphology that imposes a particular syllable ‘template’ onto the root: this ‘template’ determines the length of the stem vowel and its tone, ignoring and replacing the lexical properties of tone and vowel length. Forms associated with templatic morphology are always identically structured for all verbal roots, with no exceptional forms and neutralized distinctions between inflectional classes. The centripetal morphology illustrated by *jṳ̀ṳṳr* above is one example of a templatic morpheme. Deverbal agentive nouns, discussed in Section 4, present another example of templatic morphology. Importantly, the rising tone, with its complex tonal melody LH, is never assigned by templatic morphology. Templatic morphology appears to target the syllable as the TBU, ignoring all finer (i.e., moraic) distinctions within the root. Consequently, the templatic tonal melody can consist of a single tonal autosegment only: H or L.

To summarize, in most contexts, rising and low tones are allotones of each other based on the syllable’s vowel length/moraic structure. However, the Low toneme arises also by templatic morphology, where L is assigned to the whole syllable and in the context of polar tones, where suffixes are assigned L-tones after stems with high or falling tones.

This observation is a relevant one in the context of this article: since the distribution of the underlying low level (L) vs. contoured (LH) tones is determined by vowel length (discounting replacive or ‘templatic’ tones),[18] the contrast between the two tones is unlikely to bear a high functional load. Assuming that the distribution of high level (H) vs. contoured (HL) tones in the underlying structures is guided by the same phonological principles as the distribution of low (L) and rising (LH) tones, i.e., it is determined primarily by the length of the root vowel, the full neutralization of the two tonemes on the surface should not engender excessive ambiguity. Note also that the Rising toneme has a low allotone phrase-finally (Monich 2020); this means that, in parallel to High and Falling tonemes, the Rising and Low tonemes also neutralize based on surface phonetic factors, albeit in much more limited settings.

6 Phonetic details

This section provides phonetic details and instrumental measurements which offer clues to the nature of the phonation-based allotony in Nuer. Specifically, two questions are considered: 1) how the phonemic difference in voice quality is implemented phonetically in Nuer, and 2) what the measurable differences are in f0 contours of high and falling tones. The measurements of these phonetic parameters are based on a single Nuer speaker, whose background is described in Section 2. Each of the mini-studies conducted in this article functions as a preliminary investigation with the potential to be extended to more speakers for confirmation of the findings. In Section 7, an analysis and explanation of the phenomenon are attempted based on the observations in this section.

[18] Templatic morphology inherently introduces some degree of lexical ambiguity, as it erases distinctions between roots that belong to different tone-length classes but are otherwise identical: for example, the agentive nominalizations derived from verbs *ŋʊl* ‘shape/mould’ and *ŋʊʊl* ‘spit’ via templatic morphology will be homophonous, with *ŋṳ́ṳṳl* meaning both ‘spitter’ and ‘shaper’.

6.1 Phonetic correlates of the modal vs breathy contrast in Nuer vowels

We begin the examination of the nature of phonation contrast in Nuer vowels by identifying those phonetic correlates of breathy vs. modal phonation contrast in Nuer that may play a role in the alternation between high and falling tones.

When Nuer speakers pronounce breathy vowels in isolation – without the context of a syllable – the breathy component can be clearly heard as a kind of aspiration that precedes the vowel in lieu of an onset. Ordinarily, however, this breathy component can be hard to perceive, especially for non-native speakers. Fortunately, identification of vowels is aided by the fact that for many breathy/modal phonemic pairs, the contrast in phonation is accompanied by differences in other properties – most notably, distinctions in the ATR property and vowel height.

Figure 27 shows the mapping of Nuer vowels in the phonetic space based on the values of the first two formants (see also Reid (in press) for a similar presentation based on the speech of other speakers). The formant measurements are based on values collected for 22-98 tokens for each monophthong (depending on vowel frequency). The only monophthong absent from this chart is /ɛ̤/ – a vowel that has a marginal presence in Nuer, having been found to occur in two nouns only.

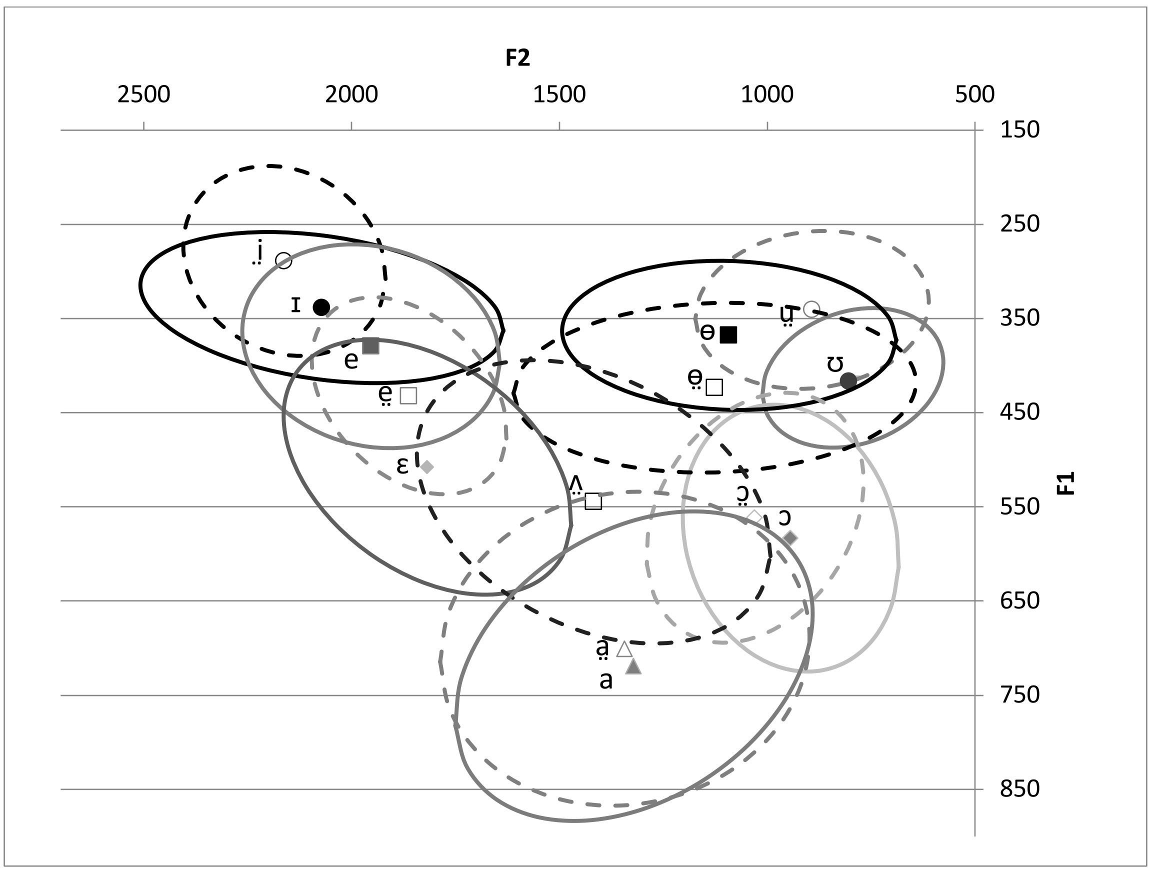

Figure 27: F1 and F2 of 14 Nuer monophthongs (Means are indicated with filled shapes for modal vowels, and with outlined shapes for breathy vowels; ellipses represent 95% confidence intervals indicated with solid lines for modal vowels and dashed lines for breathy vowels)

Figure 27 maps monophthongs of both basic and modified varieties in the acoustic space. Recall that basic vowels can be found in morphologically basic, i.e., root, forms, while their modified variants are found in some inflected forms. Proto-Western-Nilotic had a 10-vowel phonemic system based on the opposition in ATR values without the phonation contrast. Such systems are still attested in various languages of the Luo and Burun subbranches of Western Nilotic (Andersen 1999a,b). Non-modal vowel phonation emerged in the Dinka-Nuer group of Western Nilotic languages when [+ATR] vowels developed breathy voice quality. When we confine our view to the set of 10 basic (i.e., non-mutated) phonemes, which are direct reflexes of the 10 Proto-Western-Nilotic vowels,[19] we find that breathy vowels are slightly higher than their modal counterparts and are also distinct in their ATR properties: /i̤/ and /ɪ/, /e̤/ and /ɛ/, /ṳ/ and /ʊ/, /o̤/ and /ɔ/, /ʌ̤/ and /a/. In contrast, the modal vowels that developed in the more recent history as inflectional (mutated) variants of the corresponding basic breathy vowels are higher than their breathy counterparts, not lower, and have the same ATR properties: /e/ and /e̤/, /ɵ/ and /o̤/.[20] Since lower F1 is a secondary phonetic characteristic distinguishing the original [+ATR] vowels from their [-ATR] counterparts, it is plausible that this characteristic is exaggerated in /e/ and /ɵ/ in order to facilitate identification of these modal vowels as [+ATR]. At the same time, the newly added breathy vowels /ɔ̤/ and /a̤/ are pretty much of the same height as their pre-existing modal counterparts /ɔ/ and /a/.

To summarize, for most vowel pairs with opposite phonation values, the contrast in voice quality is accompanied by differences in height and tenseness (ATR), which aid in identifying the phoneme. The phonemic pairings that rely on phonation differences the most are /ɔ̤/ ~ /ɔ/ and /a̤/ ~ /a/. Consequently, the vowels /ɔ̤/ and /a̤/ can be expected to manifest phonation cues with a greater degree of clarity and consistency than other breathy vowels. Perceptually, this is indeed so. We, therefore, focus on the modal ~ breathy pair /a/ ~ /a̤/ in search for measurable correlates of the phonemic breathiness.[21]

Table 11 shows measurements of spectral balance for modal and breathy low [-ATR] vowels. Spectral balance, a parameter that refers to a difference between the amplitudes of the first and the second harmonics (H1-H2), is an effective measure of breathiness in many languages (Blankenship 2002; Garellek & Keating 2011; Wayland & Jongman 2003; Andruski & Ratliff 2000; DiCanio 2009; Esposito 2010 among others). In fact, Esposito & Khan (2020) conclude that this parameter might be the (near)-universal marker of breathiness in the world's languages. Higher values of spectral balance correlate with breathy phonation, while lower values correlate with modal or creaky phonation. Here the 'corrected' spectral measurements (H1*-H2*) are used, which compensate for the influence of surrounding formant frequencies (Iseli et al. 2007). The spectral measurements were collected using VoiceSauce software (Shue et al. 2009). Only overlong vowels were chosen for this study without consideration for their tonal specification. Lexical items containing a glide in the onset of the vowel were excluded.[22] Sample lexical items that served as the source of vowel tokens are *bâaar* 'lake.SG.GEN', *màaað-ɛ̂* 'drink.CAUS-3SG', *gá̤̤a̤a̤k-à̤* 'lock.TR-1SG', *gà̤̤a̤a̤k* 'lock.SG.NOM', etc. There were 119 tokens in the elicited corpus, which satisfied the chosen criteria (overlong low [-ATR] vowel): 56 breathy vowels and 63 modal vowels.

We find a strong correlation between higher H1*-H2* values and breathiness voice quality. The H1*-H2* values averaged across the vowel duration are at 7.94 dB (n =56, SD = 3.3) for breathy vowels and at 3.17 dB (n = 63, SD = 2.8) for modal vowels. The values of the H1*-H2* parameter are greater for vowels with breathy phonation than for modal vowels, as expected based on existing crosslinguistic studies. When the data is sorted based on the tonal characteristics of the vowels, an even neater pattern emerges. Table 11 below shows spectral balance values for breathy and modal vowels by grouping the two allotones of the

[19] The vowels /ɔ̤/ and /ɛ̤/ are thereby excluded, although these vowels are part of the 'basic' set in Table 2. These vowels arose from PWN *o and *e correspondingly, just as /o̤/ and /e̤/ did, but lost their [+ATR] property in specific morphophonological contexts. The vowel /ɛ̤/ especially is marginal in Nuer, occurring only under exceedingly rare conditions.

[20] This point, with some slight distinctions, is also made in Reid (in press).

[21] Additional considerations guide the choice of the /a̤/ ~ /a/ pair. The contrast between the vowels /ɔ̤/ and /ɔ/ may, in fact, be associated with a difference in quality when the time course of the whole vowel is considered. The breathy vowel /ɔ̤/ shows an increase in F1 and F2 towards the end of the vowel, while the modal vowel /ɔ/ shows either no change in formants or a lowering of F1 and F2.

[22] The glide in the onset vocalizes in overlong vowels taking up a significant portion of it, resulting phonetically in a diphthong. The voice quality of the vocalized glide has not been determined at this point.

High toneme (i.e., high level and falling tones) separately from those of the two lower tonemes (i.e., Low and Rising). The same data is presented visually in Figure 28.

Table 11: H1*-H2* values (dB) averaged over the duration the vowel and grouped by tone type

Breathy		Modal	
High	Low/Rising	Falling	Low/Rising,
7.87 (n=35; SD=2.1)	8.05 (n=21; SD=4.8)	2.09 (n=43; SD=2.5)	5.5 (n=20; SD=1.8)

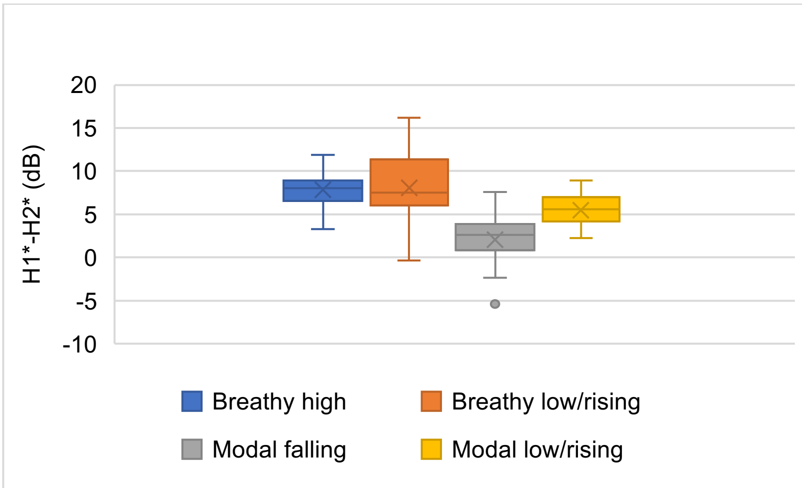

Figure 28: H1*-H2* values (dB) averaged over the duration of the vowel and grouped by tone type

When grouping the values by tone, we find that the difference between spectral values of vowels associated with the High toneme is even greater: ≈7.9 dB for breathy vowels and ≈2.1 dB for modal vowels. This result shows a statistically significant ($p <.01$) relationship between H1*-H2* values and vowel phonation.

In modal vowels associated with the two lower tonemes, i.e., Low and Rising, the spectral balance values are appreciably higher than in modal vowels associated with the falling tone: 5.5 dB and 2.1 dB, respectively. Comparing the H1*-H2* values of modal and breathy vowels associated with Low/Rising tonemes does not yield a statistically significant correlation between phonation and spectral tilt values for $p < .01$. Based on these results, it may be inferred that low pitch affects spectral values in a way that is similar to breathiness.

Focusing on vowels associated with the High toneme only, Figure 29 shows the time course of spectral balance values in breathy and modal low vowels. In order to collect these measurements, vowel tokens were divided into 10 equal parts, and the H1*-H2* values were averaged over each of the 10 intervals.

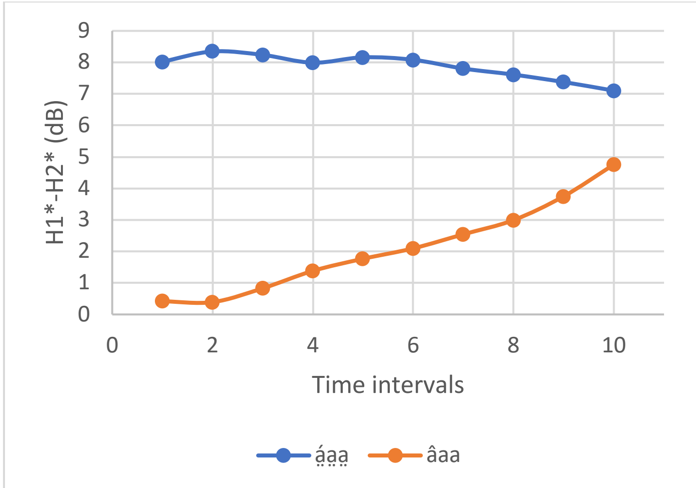

Figure 29: Time-course of the average H1*-H2* values (dB) for breathy and modal low vowels associated with the High toneme

We can draw several conclusions based on the graph in Figure 29. Foremost, we can confirm that the property of breathiness in Nuer is associated with higher spectral balance values (H1*-H2*), a cross-linguistically common acoustic correlate of breathy voice quality. Moreover, the breathy phonation is maintained throughout the vowel instead of being localized to a portion of the vowel, as is the case in some other languages (Silverman 1995). In fact, the graph in Figure 29 suggests that it is modal vowels that shift towards breathier phonation in the course of their duration. Although, when considered by itself, this result may seem surprising, it is less so in the context of the observation made earlier in this section that modal vowels with Low and Rising tonemes display H1*-H2* values more typical of their breathy counterparts. If lower f0 is associated with higher spectral balance values, a modal vowel with a falling tonal contour is expected to become breathier toward the end of its articulation. As a result of this relationship between phonation and frequency, the maximum contrast in voice quality is localized at the start of the vowel. The H1*-H2* values of modal and breathy vowels associated with the High toneme start out at the extreme ends of the spectrum and then converge toward the end of the vowel. These observations are important for understanding the nature of phonation/tone interaction in Nuer and will be revisited in Section 7.

We conclude the examination of phonation contrasts in Nuer by looking into whether there is a correlation between phonation and vowel length. If modal vowels were longer in duration than breathy vowels, the alternation between the high level and the falling tonal contours could be conceivably linked to this difference.

Table 12 shows the average duration of mid monophthongs in three length grades. The number of tokens and the standard deviation are provided in the parenthesis after each duration value. The data used to measure vowel duration was comprised of unsuffixed nominal forms and thus consisted of closed syllables only. Only unmodified nominal forms were used for measuring the duration of short and long vowels. Overlong vowels are inherently a product of morphological modification, as was described earlier. Only mid vowels were chosen for this study as vowel height was found to affect the duration of the vowel, with high vowels being significantly shorter in duration on average and low vowels being significantly longer. In order to control for these effects of vowel quality, the set of vowels used for the measurements of vowel duration consisted of mid phonemes /ɔ, ɛ, ɔ̤, e̤, ɛ̤/.

Table 12: Average durations (ms) of breathy and modal monophthongs – mid vowels only

	Breathy	Modal
Short vowels	80 (n=26; SD=13)	74 (n=112; SD=15)
Long vowels	109 (n=36; SD =21)	116 (n=40; SD=20)
Overlong vowels	228 (n=60; SD=60)	224 (n=106; SD=55)

Measurements in Table 12 do not indicate any statistically significant differences in the length of breathy and modal vowels. The falling contour over modal vowels is not conditioned by factors related to vowel duration.

In the remainder of this section, the high level and falling tonal contours are examined more closely, focusing on those properties that may hold a clue to the nature of the interaction between the tone patterns and voice quality in Nuer.

6.2 The trajectory of f0 in high level vs falling tonal contours

In Section 4, the high level and falling tones were illustrated with a number of pitch tracks. At that time, it was noted that the high level tone shows minor fluctuations in f0 – usually a slight rise at the start of the vowel and a slight decline towards its end. On the other hand, the falling tone is distinguished by an earlier peak right at the start of the vowel and a sharp and precipitous drop in f0, reaching the bottom of the speaker's frequency range by the end of the syllable. Below we approach these features of the two tonal contours quantitatively.

The falling tone has a relatively wide pitch range: in a monosyllabic word with an overlong vowel (i.e., CVVVC syllable) positioned between two low tones, the minimal measured difference between the frequency extrema was 37Hz and the maximal measured difference was 93Hz. The average fundamental frequency range of falling tones in this environment was 56.67 Hz (n=20, SD = 15Hz). The f0 peaks close to the start of the vowel and reaches its lowest point at the end of the sonorant portion of the rhyme. This means that in syllables with sonorant codas, the f0 continues to decrease through the coda, but in syllables with non-sonorant codas, the fall is completed at the end of the vowel. Due to this factor, the frequency range of the falling tone is on average greater in sonorant-final syllables than in stop-final ones.

Figure 30 plots f0 of several deverbal agent nouns pronounced in identical environments: phrase-medially, preceded and followed by low tones. As described in Section 4, all agent nouns are derived from the verbal root using the same non-segmental morphology. As a result of these morphological operations, all agent nouns have an overlong stem vowel associated with a High toneme throughout the paradigm. Plural agents are different from singular agents only in having modified vowel quality (i.e., the vowel of the stem belongs to the 'modified' set in Table 2). All examples in Figure 30 contain vowels /e̤/ or /ɵ̤/ in the nominative singular form so that the corresponding modified variant of the vowel in the plural form is the modal vowel /e/ or /ɵ/. This difference is accompanied by the appropriate contrast in the realization of the High toneme: the high level allotone in singular agent forms and the falling allotone in plural agent forms.

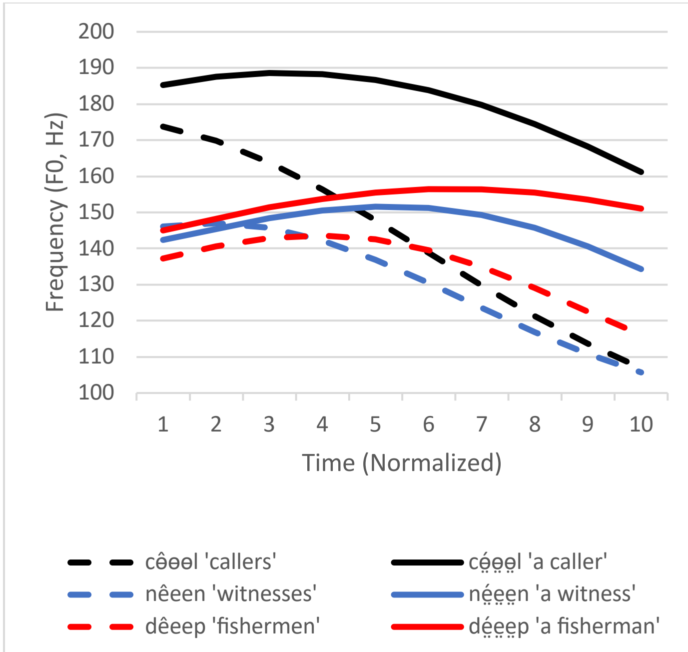

Figure 30: Influence of adjacent consonants on f0

Significantly, Figure 30 shows that the absolute starting pitch of the stem syllable is determined primarily by the voicing of the onset consonant, not by the phonation of the vowel. Syllables beginning with a voiceless stop start on a higher pitch than those beginning with a voiced stop or a sonorant. The starting f0 of nouns *cɵ̤́ɵ̤l* and *cɵ̂ɵl* is at least 30Hz higher than that of nouns *nêeen, nḛ́ḛḛn, dêeep* and *dḛ́ḛḛp*. Moreover, the overall tonal contour can be related to the phonation of the stem-final consonant also, where again, voicelessness is associated with a higher f0, while voicing is associated with a lower f0. This is especially evident in the realization of the level allotone of the high toneme: the f0 rises slightly towards the end of the syllable in *dḛ́ḛḛp,* but lowers in sonorant-final *cɵ̤́ɵ̤l* and *nḛ́ḛḛn.*[23]

The lowering effect of consonantal voicing on the f0 of adjacent vowels is well-documented and widely known (House and Fairbanks 1953; Lehiste and Petersen 1961; Hombert 1978; Jun 1996; Hanson 2008). Considered by themselves, these minor fluctuations in the fundamental frequency of the High toneme are not that interesting. They become more intriguing when the time course of f0 in falling and high level allotones is compared in the context of similarly voiced onsets.

As previously noted, in high level tones, the f0 usually peaks not at the very starting point of the vowel but with a slight delay. In other words, high level tones are actually pronounced with a slight rise. The rise is not dramatic enough for the high tone to be misidentified as the Rising toneme. However, practically always, the f0 of the high level allotone of the High toneme reaches its maximum later than in the falling allotone in phonologically identical environments. Figure 30 illustrates this tendency. The frequency peak comes right at the beginning of the vowel in *cɵ̂ɵl* and is followed by a steep fall. In *nêeen,* the frequency peak comes close to the start of the vowel, but the fall is somewhat delayed in comparison to *cɵ̂ɵl.* In *dêeep,* the f0 peaks slightly later in the vowel's first half due to the voiced consonant's depressing influence. By comparison, the f0 maximum of the high level tone in *cɵ̤́ɵ̤l, nḛ́ḛḛn* and *dḛ́ḛḛp* in each case arrives later than in the corresponding falling tone. In *cɵ̤́ɵ̤l,* the f0 peaks shortly after the beginning of the vowel, in *nḛ́ḛḛn* the frequency maximum is located at about the half point through the vowel, and in *dḛ́ḛḛp* it arrives in the second half of the vowel, later than the already delayed frequency peak in *dêeep*.

[23] Due to final devoicing, there are no examples with word-final voiced stops.

These findings are extended to 20 tokens for each combination of an initial consonant type with one of the two allotones of the High toneme and summarized in Table 14.

Table 14: Mean starting f0 (Hz), mean f0 maximum (Hz), mean f0 range (Hz) = $f0_{max}$-$f0_{min}$ and mean timing of $f0_{max}$ (% of the vowel length) in high and falling allotones of the High toneme

Onset consonant	Value	Falling allotone		High level allotone	
		Mean	SD	Mean	SD
Voiceless Stop	Starting f0	160	13	161	23
	Peak f0	160	13	164	25
	Timing of f0 max.	0	0	0.28	0.25
	f0 range	67	12	11	5
Sonorant	Starting f0	137	13	144	12
	Peak f0	146	14	163	13
	Timing of f0 max.	0.21	0.11	0.45	0.13
	f0 range	47	11	19	9
Voiced Stop	Starting f0	130	13	127	8
	Peak f0	148	17	149	11
	Timing of f0 max.	0.28	0.07	0.5	0.12
	f0 range	54	14	23	9

As Table 14 shows, the average starting f0 strongly correlates with the properties of the syllable onset. Both high level and falling tones start out significantly higher after voiceless stops than following voiced sonorants and stops. Reliably, the fundamental frequency peak arrives later (by 0.25% of the vowel length on average) in high level tones than in falling tones following onsets with similar properties. Since high level and falling tones are in complementary distribution based on the voice quality of the vowel, this finding can be recast in terms of vowel phonation. The fact that after similarly voiced onsets, the f0 peaks later in breathy vowels than in modal vowels furnishes an important clue to the origin of the phonation-based allotony in Nuer. We will come back to this observation in Section 7.

There is another consonant that triggers even a greater perturbation of onset f0: the fricative /ɦ/. When followed by a breathy vowel associated with a High toneme, this consonant causes a significant lowering of the initial f0: on average, f0 in breathy vowels with /ɦ/ in the onset start out 42 Hz lower than the f0 peak, which is attained at 0.6 of the vowel length. Both of these measurements exceed those recorded for other voiced consonants in Table 14. As the onset to modal vowels, the voiced glottal fricative /ɦ/ is either devoiced (i.e., /h/) or completely absent and thus does not impact the tonal contour of the vowel (i.e., /ɦɔ́ɔɔkɛ̀/ =[ɔ̂ɔɔkɛ̀] 'push.TR-3SG'). Therefore, there exists a close connection between the consonant /ɦ/ and vowel phonation: on the one hand, the onset /ɦ/ is incompatible with a following modal vowel; on the other, it serves as an amplifier for properties associated with breathiness when the following vowel is breathy, including a relative delay in in the attainment of the f0 target. As pointed out in DiCanio (2008), the production of /ɦ/ is similar to that of breathy phonation, and both are associated with pitch lowering.

We conclude our description of the phenomenon by noting that the relationship between the realization of the High toneme and the phonation of the vowel is very robust. It may even be that the choice of the correct allotone of the High toneme is crucial to properly identifying vowel phonation. In our experience, vowels pronounced with correct phonation but incorrect tonal contour are perceived by native speakers to have unintended phonation. For example, the word *tîik* ‘bead.SG’ pronounced with high level pitch is recognized as *t̪i̤i̤k* by Nuer speakers and may be confused with similar lexical items, such as *t̪í̤i̤k* ‘cloud over sun’ or *t̪í̤k* ‘chin’. The falling pitch is crucial for correctly perceiving the vowel as modal. Further experimental work is required to ascertain whether these purely impressionistic observations can be empirically confirmed.

In the next section, we tackle the question of what may motivate the unusual phonation-triggered allotony in Nuer and consider the phenomenon within a broader typological context.

7 In search of an explanation

Cross-linguistically, phonation and tone are often found to interact and influence each other. The two properties are especially inextricably connected in the so-called ‘register’ languages, where some or all tones are associated with specific voice quality. The Mon-Khmer language Chong (DiCanio 2009) offers one of the more extreme cases. In this language, a four-way contrast in phonation corresponds to a four-way contrast in tonal contour and pitch level. Tone 1 is a level tone pronounced in the middle pitch range with modal phonation. Tone 2 is higher in pitch and laryngealized at the end. Tone 3 is a falling tone pronounced with breathy phonation. Tone 4 is a falling tone higher in pitch than Tone 3 and ending with laryngealization.

In other ‘register’ languages, correlation between tone and phonation may be more limited. In White Hmong (Ratcliff 1992; Esposito 2012; Garellek et al. 2013), two of seven tones are associated with non-modal phonation. There is a breathy tone that is pronounced with a mid- or high-falling pitch contour, and a creaky tone that is pronounced with a low-falling pitch contour. The other five tones are found on vowels with modal voice quality. White Hmong illustrates the general tendency for tonal contrasts to be limited on vowels with non-modal phonation.

Languages with fully independent parameters of tone and phonation, i.e., those that cross-classify tone and voice quality, are rare and so far have been attested mainly in two language families: Otomanguean and Western Nilotic (Garellek & Keating 2011, p. 186).[24] For example, in Jalapa Mazatec, an Otomanguean language, vowels may be modal, breathy, or creaky and associated with level tones H, M, L or contour tones LM, LH, ML, MH, HL, HM, LML, LHL, MHL. The complexity of such systems presents an extreme case where the perception of tonal contrasts could potentially be hindered by interaction with phonation. As argued in Silverman (1995), in Otomanguean languages, the challenge posed by the interaction of pitch and voice quality is tackled by sequencing phonation and tone signals within the same vowel so that only a part of the vowel manifests characteristics of the non-modal phonation, while other parts of the vowels are characterized by modal phonation and the appropriate tonal contour.

Some Nilotic languages, most notably Dinka, are also known to cross-classify tone and voice quality, although within a smaller tonal inventory than seen in Otomanguean languages like Jalapa Mazatec. Dinka combines breathy and modal phonation with either of the four tonal contours (H, L, HL, LH) in all possible combinations (Remijsen & Manyang 2009).

Although the interaction of breathiness with tone is documented and expected, we find no exact parallels to Nuer, i.e., no comparable cases where the tonal contour is modified due to the voice quality of

[24] Phonation and tone are also reported to be orthogonal in Yi languages (Kuang 2011, 2013). However, the two properties in Yi languages do not appear to be cross-referenced as freely as in Otomanguean and Western Nilotic languages since phonation contrasts are absent on high-toned vowels.

the vowel. Moreover, the phonation's effect on pitch contour in Nuer – the sharp lowering of f0 towards the end of modal vowels and, by comparison, higher pitch towards the end of breathy vowels – is surprising. From a brief survey of literature on the interaction of phonation and tone, it appears that the overwhelming tendency is for breathy voice quality to be associated with a lowering in pitch (Gordon & Ladefoged 2001; Hombert et al. 1979; DiCanio 2008).

For example, Silverman (1997) reports that in Jalapa Mazatec, where non-modal phonation affects only a portion of the vowel, the breathy component of a high-toned vowel is lower in pitch than its modal component. Andruski and Ratliff (2000) likewise report lower fundamental frequency for breathy vowels. DiCanio (2008) finds that breathy phonation in San Martín Itunyoso Trique (preceding post-vocalic /h/) is associated with pitch-lowering in the upper-frequency range but does not affect low and mid-range tones.

The lowering effects of breathy voice have been credited in several models of tonogenesis. For example, Svantesson and House (2006) propose that tonal contrasts in Kammu arose due to breathy~modal contrasts in vowels. Voiced consonants in this language became devoiced but conditioned breathiness in the following vowels; eventually, the breathiness translated into the vowels being comparatively lower in pitch. Breathy-voiced consonants also are known to act as tonal depressors (Hombert et al. 1979). For example, in Punjabi, breathy consonants yielded low tones on the following vowels (Gill and Gleason 1969, 1972; Haudricourt 1972). Breathy consonants in codas have similar effects. A well-known case of this comes from Vietnamese, where the word-final /h/ lowered pitch of the vowel (Haudricourt 1954).

The lowering of f0 over breathy vowels makes sense physiologically; during the production of breathy vowels, the vocal folds are relatively more relaxed than during modal phonation. A more fine-grained explanation of physiological reasons for the correlation between breathiness and frequency lowering can be found in Hombert (1978) and Silverman (1997). Cases where breathiness is associated with higher f0, are few in between and are mostly either inconsistent or can be tied to breathy phonation only indirectly. For example, although Wayland and Jongman (2003) found that in Chanthaburi Khmer, breathy vowels have a higher f0 than clear vowels, the difference was significant for only two out of five participants in the study. Thurgood (2004) reports a higher f0 for some vowels (i.e., /ṳ/) in Javanese but the opposite for others (i.e., /a̤/). Moreover, in this language, the place of articulation of the onset consonant appears to play an important role in the pitch of the vowel. DiCanio (2008) presents a case in Itunyoso Trique where the only two rising tones (with pitch contours 13 and 35) in the system, which otherwise distinguishes 4 tonal levels, are found exclusively on breathy vowels (i.e., those in syllables with /h/ in the coda). Potentially this language could furnish a case where breathiness is associated with a higher pitch towards the end of the vowel, like in Nuer. However, DiCanio argues, based on experimental and phonetic data, that breathiness in Itunyoso Trique is actually associated with a lowering in f0. The appearance of rising tones on breathy vowels is due to the longer persistence of voicing in breathy vowels in this language. The longer duration of the vowel permits the underlying rising tones to surface. By contrast, the /ʔ/-final syllables, which have the shortest duration, do not allow any contour tones. In other words, the rise in f0 in Itunyoso Trique is not a result of f0 perturbation due to breathiness but rather a manifestation of the underlying tonal melody fully realized due to vowel length.

Truly convincing examples of breathiness associated with a raised f0 are hard to come by. DiCanio (2008) states explicitly that cases where the pitch is raised due to the breathy phonation of a vowel are not found. According to his cross-linguistic overview of breathiness~pitch interaction, all attested cases where breathiness is responsible for raised pitch are those where breathiness is a property of a consonant and not of a vowel. For example, aspirated stops are associated with an increase in f0 relative to unaspirated stops in Korean and English (Hombert 1975; Hardcastle 1973; Cho et al. 2002). Nevertheless, according to Silverman's (1997) model of phonation~tone interaction, breathy vowels may develop rising tones due to a compensatory increase in subglottal pressure. Silverman (1997) cites Jeh (Gradin 1996) and Quiotepec Chinantec (Robbins 1968) as possible cases illustrating this kind of development.

Among the examples cited, we do not find any exact parallels to the interaction between phonation and tone we find in Nuer. Still, a typologically plausible scenario for the emergence of this interaction can be imagined if we take into account some of the phonetic observations made in Section 6. It is possible that breathiness in Nuer became associated with lowered f0 at the start of the vowel, while the overall contour was kept relatively level to preserve contrast with the Rising toneme. The comparatively higher initial f0 of the High toneme in modal vowels could then have become phonologized as a fall.

At first glance, this account is contradicted by the observation made in Section 6 that there is no clear correlation between breathy phonation and a lowered starting f0. Instead, the factor which impacts the starting f0 of the High toneme the most is the phonation of the onset consonant: syllables with voiced onsets begin on a pitch lower than those with voiceless onsets. Though evidence that breathy vowels consistently begin at a lower pitch is lacking, we can approach the same issue from a different angle. In Section 6, we noted that high level tones are not entirely level and tend to rise slightly. Interestingly, although the mean pitch maxima are not significantly distinct in modal and breathy vowels, the target frequency peak arrives early when phonation is modal, while in breathy vowels, it is substantially delayed. From the physiological point of view, the rise may be caused by an increase in subglottal pressure. Along the lines suggested in Silverman (1997), subglottal pressure may be increased to compensate for the inherently lower rate of vocal cords vibration in a breathy vowel and the consequent ‘undershooting’ of the intended pitch target. The resulting rise in pitch is moderate: it is less dramatic than the one observed in vowels associated with the Rising toneme and even may be absent entirely when the intended pitch target is reached outright (usually after voiceless onsets, which do not introduce additional lowering effects). Nevertheless, this rise could hold the key to the historical development of the allotony based on vowel phonation. Instead of comparing the absolute values of the starting f0 in modal and breathy vowels, we may suppose that the High toneme in breathy vowels came to be differentiated by the relatively late timing of the fundamental frequency peak in comparison to modal vowels. It is conceivable that the earlier timing of the frequency peak in modal vowels came to be perceived as frequency lowering in the subsequent portion of the vowel. This perception of a fall then plausibly became phonologized as the allotonic rule ‘H → HL, if modal’. By the same logic, the delayed peak in f0 of breathy vowels associated with an underlying HL tonal melody came to be interpreted as an absence of the fall compared to modal vowels, eventually phonologizing as a rule deleting an L after H in vowels with breathy phonation.

This view of the relationship between f0 and phonation in Nuer is further supported by the two observations regarding the spectral tilt measurements in Section 6. As noted there, the H1*-H2* values indicate that there indeed exists a connection between lower pitch and breathiness in Nuer: modal vowels associated with the lower tonemes (L and LH) acquire breathy character, as reflected in their spectral balance measurements which are comparable to those of breathy vowels. It is easy to imagine that this interaction of phonation and tone goes both ways and that, by a similar token, breathy vowels are lowered in pitch. Additionally, it was observed in Section 6 that the contrast in the spectral values of breathy and modal vowels is most significant at the start of the vowel. This finding is likewise consistent with the proposal made here, which tracks the origin of the phonation-based allotony in Nuer to the relative difference in the starting pitch level – raised pitch at the start of modal vowels in contrast to the lowered pitch at the start of breathy vowels. According to this view, the difference in the ending frequency of the two allotones is just a by-product of the starting frequency difference, but one which became exaggerated as the most salient feature setting them apart and, eventually, phonologized.

While the scenario outlined in this section seems plausible, it does not entirely account for the motivation for the phonologization of the relative timing in the f0 peak as a fall over modal vowels rather than a rise over breathy vowels. In other words, the same phonetic difference could have been phonologized as a rule inserting an L before an H in breathy vowels and removing an L before an H in modal vowels. If such development had occurred, Nuer would have neutralized the opposition between underlying H and LH instead.

Two factors would have made this alternative scenario unlikely to take place. First, the conflation of the underlying H and LH tonal contours would have introduced much more lexical ambiguity than conflation of H and HL. As suggested at the end of Section 5, if the distribution of the underlying H and

HL tones indeed parallels the distribution of L and LH, then the two are allotones in most (but not all) contexts to begin with.

The alternative scenario is also implausible in view of typological considerations. Based on the cross-linguistic overview in this section, we conclude that there are two kinds of languages with phonemic oppositions in both tone and voice quality: those where the non-modal phonation is limited to specific tones (like Chong and Hmong) and those where phonation and tone are sequenced in production in order to not interfere with each other (Jalapa Mazatec). With the notable exception of Dinka – a language closely related to Nuer and possibly documenting an earlier stage in its development in regards to this phenomenon – we do not find languages where tone and phonation properties exist completely orthogonally to each other so that different values of the two characteristics may be combined in all possible permutations. Since execution and recognition of complex tonal melodies in languages without contrastive vowel phonation (i.e., those with modal phonation only) is not problematic, what seems to create an issue for speakers is maintaining and/or identifying tonal contrasts in vowels with non-modal phonation. This generalization is largely confirmed in Silverman (1997), where possible acoustic/perceptual reasons for the difficulty in identifying the correct tonal characteristics of vowels with non-modal phonation are briefly discussed.

The difficulty in executing both non-modal phonation and tone is more pronounced when the tonal melody is complex and therefore demands controlled changes in the vibration of the vocal cords while maintaining them in the abducted state (for breathy voice). Under the imaginary alternative scenario where the phonetic difference in timing of the fundamental frequency peak became phonologized as a rule inserting L at the start of breathy vowels, Nuer speakers would have been tasked with execution and discernment of two complex melodies on breathy vowels: LH and HL. Based on the cross-linguistic trends highlighted in this survey, that would have presented a typologically unlikely situation. The rule that was adopted instead, removed one of the complex tones – namely HL – from the inventory of tones co-occurring with breathy phonation. In fact, the HL tonal contour would have been especially challenging to execute in breathy vowels, considering that it would have involved a fall after a late frequency peak. By contrast, execution of the complex tonal contour of the Rising toneme (LH) over a breathy vowel only requires a start at a lower pitch than the corresponding High toneme, and as such is not particularly problematic.

Therefore, even though at first glance typologically unique, the interaction of phonation and tone in Nuer is motivated by the same tendency to avoid complex tonal contrasts on vowels with non-standard phonation that is documented in other languages. The problem of executing and signaling both properties simultaneously is resolved either by pairing a specific tonal melody with a specific phonation type so that ambiguity does not arise (as in Mon-Khmer languages discussed above); or by sequencing tonal and voice quality characteristics within the same syllable (as in Jalapa Mazatec); or, as in Nuer, by reducing some tonal oppositions based on vowel phonation. In Nuer, the neutralization is incomplete, and tone and phonation are still largely independent from each other: three of the four underlying tonal contrasts are found on each vowel. However, execution of the most challenging tonal contour – an HL sequence on a breathy vowel – is avoided by neutralizing the High and the Falling tonemes based on vowel phonation.

Abbreviations

AP = antipassive
APPL = applicative
CAUS = causative
CF = centrifugal
CP = centripetal
EXCL = exclusive
GEN = genitive
INCL = inclusive
LOC = locative
MULT = multiplicative
NOM = nominative
NSF = non-suffixed form
OBL = oblique
PL = plural
PREP = preposition
SG = singular
TR = transitive

Appendix A: List of frames for the elicitation of nouns

1. tîɛɛɛmʌ̤̀/nɛ̂aaanʌ̤̀ X (kɛ t̪jâŋ). ‘I remember/see X (in the evening).’
2. rîɛɛŋʌ̤̀ X (kɛ t̪jâŋ). ‘I run to X (in the evening).’
3. gêɵɵrʌ̤̀ cā̤a̤r X (kɛ t̪jâŋ). ‘I want to think about X (in the evening).’
4. tɛ̂ɛɛ a X (kɛ t̪jâŋ). ‘He is at X (in the evening).’
5. rı̤̆ŋ/rı̤́ŋ/(µ)cɔ̤̀a̤a̤a̤ X ‘meat (pl.)/meat (sg.)/bone of X’
6. cʌ̤́ X kɔ̂k/nɛ̂ɛn/gṳ̀ɔ̤ɔ̤ɔ̤r. ‘I bought/saw/followed X.’
7. cʌ̤̆ X kɔ̂k/nɛ̂ɛn/gṳ̀ṳṳr. ‘I am not buying/seeing/following X.’
8. n̪ʌ̤̀k/càm/kɔ̀k X. ‘kill/eat/buy X!’
9. kɛ̂t X jié̤r ‘X is swimming (across) the river.’
10. kḛ̀t X jiĕ̤e̤e̤r ‘X is swimming in the river.’

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