Tonal Interactions in Nuer Nominal Inflection

An der Philologischen Fakultät der Universität Leipzig

eingereichte

DISSERTATION

zur Erlangung des akademischen Grades

Doctor philosophiae

(Dr. phil.)

von

Siri Moen Gjersøe

Gutachter:

Prof. Dr. Jochen Trommer
(Institut für Linguistik, Universität Leipzig)

Dr. Bert Remijsen
(Department of Linguistics and English Language,
University of Edinburgh)

Dr. Tamara Rathcke
(Department of English Language
and Linguistics, University of Kent)

Dr. Eva Zimmermann
(Institut für Linguistik, Universität Leipzig)

Datum der Einreichung: 22.05.2019
Datum der Verleihung: 03.02.2020

Acknowledgments

This dissertation would not have been possible without the help and support of many individuals and organizations. I would first like to acknowledge the DFG-funded research training group *Interaction of Grammatical Building Blocks* (IGRA) at Leipzig University, who generously financed this project. I am grateful for the time I spent at IGRA because of the knowledge I obtained there on phonological, morphological, and syntactic theory. The faculty members at the Department of Linguistics in Leipzig dedicated a great deal of time to teaching and inspiring me on these subjects, and I have received input from many great scholars who visited IGRA over the course of my Ph.D. I consider myself very lucky for the support, supervision, and funding I received with the opportunity to develop my own project and do fieldwork.

I am grateful for the support of my supervisors Jochen Trommer and Bert Remijsen, and the advisors from the extended committee Tamara Rathcke and Eva Zimmermann, who have invested their time and shared their knowledge with me, guiding me from early work–in–progress stages to the form it has now.

Jochen Trommer has an impressively deep and vast insight into phonological theory, and being in his classes was always a great benefit to my research. I feel lucky to have had such an expert phonologist to advise me, who also has a strong interest in tone and data from understudied languages. I am very grateful for having him as a supervisor because he has encouraged me to continue working on tone and has always given me the autonomy to develop my own ideas. He is an inspiring researcher, and I am extremely thankful for all his input on my analysis which lead to substantial improvements each time we talked.

I am deeply grateful for having Bert Remijsen as a co–supervisor. As an expert on the phonetics and morpho-phonology of Nilotic languages, it is difficult to think of a more suitable co-supervisor for my dissertation than Bert. He has shared his expertise and methods in phonetics and Nilotic languages with me, teaching me most of the tools I have used to develop the phonetic parts of this dissertation. I am indebted to him for all the time he dedicated to me during my stay at the University of Edinburgh, and I am extremely thankful for all his input and feedback on this dissertation. He has been a great support in challenging times during this Ph.D.; for example, when I was in the field and needed urgent advice on the topics I was working on.

Having an extended supervising committee, I have been lucky enough to get Tamara Rathcke as an advisor. As an expert on prosody and experimental phonetics, she has advised me on statistical analyses and methods in experiments. Coming from a background in theoretical linguistics, I have gained essential knowledge in phonetics from her, and I am very grateful for the time she has invested in my work, especially during my research stay at Kent University.

Eva Zimmermann has supported me in many ways during my Ph.D. She has the rare combination of being brilliant and humble at the same time and has always taken the time out of her schedule to advise me. In the course of my studies, she had the patience to read and listen to many different versions of my analysis. She advised me when I was stuck on problems and guided me to solutions with patience and encouragement. I am not sure I would have been able to finish this dissertation without her help and moral support.

There are many other scholars I have discussed my work with. I greatly acknowledge the input from Andrew Kostakis on the theoretical part, and the fruitful discussions I had with Bob Ladd. I would like to thank Anne Lerche who advised me on polynomial regression models, and Iryna Monich for sharing earlier versions of her work on tone with me. I am also grateful for having met Tatiana Reid because not only has she become a dear friend to me, but she has given me valuable feedback on my work and always answered the many questions I had on Nuer. Another person who has supported me is Joanna Zaleska, who has read early-stage chapters and always offered insightful answers to the theoretical questions I had.

I am grateful for the help I received from Lukas Urmoneit and Elena Pyatigorskaya with the Praat–annotations for the production experiments of this dissertation. I would like to thank Jade Jørgen Sandstedt for proof-reading. Jade has encouraged my work by reading it and giving me comments in the end-phase of this dissertation. For earlier versions of my thesis, I am also grateful to Daniele Sartirani and Michelle Paschen for their proof-reading.

I gratefully acknowledge the support from Anne-Christie Hellenthal and everyone else at SIL Ethiopia for their hospitality during my stay in Addis Ababa, and for organizing a desk for me and a room for my sessions. Last but not least, this dissertation is a result of the time and patience of the Nuer speakers I worked with. Taidor Lam Ruai has been a skilled, patient, and faithful informant whom I worked with over several periods, and Luke Kue Yiech has dedicated much time to this project as an informant during his stay in Leipzig. At the Addis Ababa University, Dr. Girma Mengistu Desta has been so kind to host me at the Department of Linguistics and Philology, where I met other key informants who have contributed to this thesis. John Koang Nyang has generously shared his linguistic knowledge on Nuer with me. I am grateful for the collaborations with Nyanhial Ramse Chol, Steven Läm, Gnuon Hoth Wal, and Khɔr jɔk Chol. I would also like to thank all the participants in the acoustic experiments. I am extremely grateful to the Nuer community for being so open and kind to me, making the fieldwork the most fun, fruitful, and exciting time of my studies.

Contents

Diacritics

á	High tone
à	Low tone
ā	M tone
â	Falling tone
ǎ	Rising tone
^{T}a	Floating tone in the input, e.g., ^{L}a
$^{\mathbf{T}}$a	Floating tonal tree in the input, e.g., $^{\mathbf{L}}$a
↓	Downstep
V, Vˑ, Vː	Short mid-long and long vowel

Abbreviations

C	Consonant
DOM	Differential Object Marking
F_0	Fundamental frequency
GNLA	Generalized Non-linear Affixation
H	High
JND	Just Notable Difference
L	Low
LDA	Linear Discriminant Analysis
LME	Linear Mixed Effects
M	Mid
ms	Milliseconds
OCP	Obligatory Contour Principle
OT	Optimality Theory
p-phrase	Phonological phrase
pw	Prosodic word
sd	Standard deviation
ST	Semitones
TAM	Tense Aspect Marker
TBU	Tone Bearing Unit
V	Vowel

Grammatical categories and glosses

CF	Centrifugal
CS	Construnct state
FUT	Future
GEN	Genitive
IMP	Imperative
LOC	Locative
NEG	Negation, negative
NOM	Nominative case
OBL	Oblique case
OM	Object marker
PL	Plural
POSS	Possessive marker
PREP	Preposition
PVF	Perfective
SG	Singular

Symbols

	Epenthetic material
o	(Tonal) root node
ϕ	Phonological phrase
ω	Prosodic word
σ	Syllable
#	Word boundary

Tone structures

Linked tone	Floating tonal tree	Floating tone
T	T	T
|	|	
o	o	
|		
σ	σ	σ
(Stable stem)	(Hybrid stem)	(Unstable stem)

Chapter 1

Introduction

This dissertation is on the tonal system of nouns in Nuer, a Western Nilotic language. The variety of this study is Eastern Jikany, spoken in Gambela, Ethiopia. Tone in Nuer is an understudied topic and has mostly been ignored in previous studies. Other aspects of Nuer have received more focus, especially consonant mutation (cf. Wolf, 2007; Trommer, 2011) and the suffixation patterns in nominal inflection (cf. Frank, 1999; Baerman, 2012). Nuer language is complex in the sense that it has many ways of expressing morphosyntactic categories through stem-internal modifications. In monosyllabic words, these modifications can involve length, phonation, vowel quality, diphthongization, and coda consonant alternations. If all these components are used in a language, it is perhaps expected that tone is only a by-product of other phenomena in the phonology such as vowel length or phonation, having a secondary role in the grammar. This dissertation demonstrates the opposite, namely that tone has a primary role in nominal morpho-phonology.

The contribution of this dissertation is both empirical and theoretical. In the theoretical part, I demonstrate the function of tone in nominal inflection. This part of the grammar is intriguing because it involves tonal interactions of three components: lexical tone, L tone restrictions, and inflectional tone. It is exactly these interactions which reveal the differences in the underlying tonal representations of Nuer nouns. An essential part of my proposal involves an enrichment of tonal representations to capture these underlying differences. I argue that Nuer has a bidirectional defectiveness which not only concerns affix material, but it crucially relies on tonal defectiveness in the stems. The term defectiveness refers here to featural or prosodic underspecification, but it also involves floating tonal affixes which lack segmental material. In nominal inflection, stems either get a suffix or undergo stem-internal modifications. My main claim is that the many patterns of suffixation in inflection are predictable in the data of this study. That is, the suffixation classes can be derived by general phonological principles when (i) the degree of defectiveness is taken into account, and (ii) these structures are derived in a stratal model. In this way, the surface realization of suffixation can be uniformly derived in a model where defective structures interact serially. This is implemented in Stratal Optimality Theory (Kiparsky, 2000, 2015; Bermúdez-Otero, 2011, 2012). The data and proposal of this study differs greatly from the arbitrary suffixation patterns found in Frank (1999) and Baerman (2012).

The theoretical account of Nuer tone relies heavily on the empirical part of this dissertation. Phonological categories are expected to have acoustic correlates in the production as well as perceptual cues. The main contribution here consists of novel data giving evidence of surface contrast of tone and their distributional restrictions. Concretely, I give experimental evidence of H, L, and HL tones, and provide a detailed phonetic account of the production and perception of these tones in different tonal sequences and utterance positions. I also show that some nouns surface with a mid tone which contrast with H and L tones. Tonal contrast plays a fundamental role in the morpho-phonology, and the experimental results show that this prominence is in fact reflected in the clear-cut contrast in speaker's production and listener's perception. Because this is, to my knowledge, the first acoustic study on Nuer tone, this dissertation seeks to shed light on the phonetic implementation of these tonemes.

On a larger scale, the different components of the empirical and theoretical contributions give evidence against prior assumptions that tone is not important in Nuer inflection. By bringing the focus on tone, I show how it not only plays a major role in the grammar, but also how inflection classes based on suffixation are superfluous when tone comes into the picture. That is, when tonal morpho-phonology takes the workload, an apparently arbitrary affix pattern becomes predictable.

The remainder of this chapter is structured as follows. Section 1.1 presents a background on Nuer which will be relevant for the dissertation. This involves segmental morpho-phonology, inflectional patterns, case constructions and word order. Section 1.2 describes how the data in this study were collected. In section 1.3 I present the main empirical findings which result from the experimental studies. Section 1.4 summarizes the empirical and theoretical findings on L tone distribution. Section 1.5 gives a synopsis of the proposal on tonal interaction in the nominal inflection of Nuer. The final section 1.6 provides the structure of this dissertation.

1.1 Nuer language[1]

Nuer belongs to the Nilo-Saharan language family and is classified as a Western Nilotic language belonging to the Dinka-Nuer group. The official estimation of native Nuer speakers varies between 1–3 million depending on the source.[2] The exact number of dialects in Nuer, and how

[1] For more background on Nuer language, consult Crazzolara (1933) and Faust and Grossman (2015) (grammar sketches); Storch (2005); Frank (1999); Baerman (2012) (nominal system); Yigezu (1995) and Reid (2019) (phonetics, phonology and morphology of the vowel system); Nyang (2013) (verbal morphology); Faust (2017) (reduplication); Köhler (1949); Wolf (2007); Trommer (2011) (coda-consonant mutation).

[2] Simons and Fennig (2018) estimate a Nuer population of 893,000. Two other sources estimate over 2 millions speakers: joshuaproject.net/people_groups/13909/ET: 2,381,000 speakers, https://en.wikipedia.org/wiki/Nuer_people: 2,900,000 speakers.

they differ from each other has not yet been established and is a topic of further research. There is, however, consensus on the main varieties: Western Nuer and Eastern Nuer. The former, also known as Bentiu, is spoken in the north-central part of South Sudan. The latter encompasses a large geographical area within the Jonglei and Upper Nile states in South Sudan and the Gambela region in Ethiopia.[3]

The dialect of this study is Eastern Jikany. This dialect, or 'subvariant' of Eastern Nuer, refers to different tribes located at the border areas of South Sudan and Ethiopia. In South Sudan, it is spoken in the southern part of the Upper Nile state. In Ethiopia, it is spoken in the Gambela region, located at the south-western border of the country. Some of this dissertation's results suggest that the Ethiopian variant of Eastern Jikany differs from the Eastern Jikany spoken in South Sudan. Therefore, I want to emphasize that this dissertation presents data from speakers of the Gajiök and Gajaak tribes of the Gambela area of Ethiopia – see section 1.2 for more on the language background of these speakers. The exceptions concern the experimental studies in chapter 3,4, and 6, where a few speakers from South-Sudan were included. For the topics and material tested in this experiments, the Ethiopian speakers did not differ from the South Sudanese speakers.

The principal Nuer tribe of the Gambela area is the Gajaak, but there are also many of the Gajiök tribe living there. The differences between speakers of the Gajaak and Gajiök tribes have not been studied. However, my findings indicate that the supra-segmental phonology is the same, whereas there are a few differences in the segmental phonology. When relevant, I will mention the few segmental differences I have found between these varieties.

1.1.1 Phonology

Nuer is predominantly a monosyllabic language where syllables typically have a CVC structure. One of the main characteristics of Nuer is that stem-internal changes can mark morphological categories. This makes Nuer, along with its neighboring languages the poster child of languages with non-linear morphology. In the Eastern Jikany dialect, inflection and derivation involve stem-internal changes of vowel quality, voice quality, vowel length, diphthongization, and tone.

The consonant inventory is shown in Table 1.1. It is represented in IPA and is a version adopted from Faust and Grossman (2015) who have worked with an Eastern Jikany speaker. It also is similar to the findings of Monich and Baerman (2018), who have worked with speakers of both Western and Eastern Nuer. As noted by the latter source, Eastern Nuer differs from Western Nuer in lacking fricatives. That is, Western Nuer has additional fricatives which are only contrastive in stem-final positions. This is a result of the active role of consonant mutation in this Nuer variant. The data from this dissertation on Eastern Jikany Nuer show only the two fricatives [h] and [θ]. The latter is an allophonic variant of the dental plosive /t̪/ and

[3] See Reid (2019) for more information on this with a dialect map.

is, therefore, represented in parenthesis. For example, when the dental plosive is in a final position as in *lât̪* 'cotton', a common realization by Eastern Jikany speakers is [lâθ]. In careful speech, the dental plosive is realized. Regarding the glottal fricative [h], it is marked with a star because its phonemic status is unclear. Eastern Jikany speakers use it in some words such as the first person singular pronoun *hɐ̤n*. As observed by Reid (p.c.), some speakers pronounce it as voiced: [ɦ]. In Western Nuer, speakers pronounce this pronoun as ŋɐ̤*n*.

	Bilabial	Dental	Alveolar	Palatal	Velar	Glottal
Plosive	p b	t̪ d̪	t d	c ɟ	k g	
Nasal	m	n̪	n	ɲ	ŋ	
Liquid			l			
Trill			r			
Glide	w			j		
Fricative		(θ)				*h

Table 1.1: Consonant inventory in East. Jikany Nuer based on Faust and Grossman (2015); Monich and Baerman (2018).

Nuer has a rich vowel inventory with phonemic contrast in voice quality, i.e., vowels can be breathy or modal. Breathy vowels are transcribed with the IPA diacritic for this, e.g., /a̤/. For diphthongs and long vowels, measurements indicate that the whole segment is breathy, and they are transcribed with diacritics under each vowel component, e.g., *kɔ̤́a̤ːk* 'hole'. According to the measurements done on the vowels in this study, the most reliable correlate for phonation is the intensity (dB) of the first two harmonics (H1–H2). Breathy vowels have a high value, while modal vowels have a value around 0 or negative. Examples of all the monothongs and diphthongs found in this study are given in Table 1.2–1.3. Tone is transcribed on the first vowel component showing the tone of the whole syllable, e.g., ʊ́ɔ is a H-toned diphthong.

Vowel	Example	Gloss
u	mún	'soil'
ṳ	kṳ́t̪	'gods'
ʊ	dʊ̂ˑr	'tribes'
o	lòɲ	'lion'
o̤	dó̤ːr	'tribe'
ɔ	lɔ̂ˑc	'heart'
ɔ̤	rɔ̤́ˑt̪	'armpit'
ɐ̤	wɐ̤́ˑŋ	'eyes'
a	jâŋ	'cow'
a̤	ɟá̤ˑl	'visitor'
e̤	ké̤r	'calabash plant'
e	tet	'hand'
ɛ	dɛ̂ˑp	'butter'
ɛ̤	rɛ̤́ˑt̪	'dryness' (PL)
i	dîˑt	'bird'
i̤	rí̤ˑŋ	'meat'

Table 1.2: Monothongs in Ethiopian Jikany.

Vowel	Example	Gloss
i̤e̤	cí̤e̤k	'woman'
iɛ	dìɛːt	'bird' (OBL.SG)
ɔ̤a̤	*kɔ̤́a̤ːk*	'hole'
ɔa	rɔ̀aːm	'sheep'
ṳɔ̤	bṳ́ɔ̤ːk	'Nuer god' (OBL.SG)
ɛ̤ɐ̤	tɛ̤́ɐ̤ː	'secrets'
uɔ	lûɔˑɲ	'lions'

Table 1.3: Diphthongs in Ethiopian Jikany.

The findings in Table 1.2 and 1.3 can be compared with the proposal by Reid (2019) on vowel inventory in Lɔu Nuer shown in (1). While she finds 14 monophthongs, this study also found words with the modal vowel [u] as in *mún* ‘soil’, and the breathy vowel ɛ̤. It is unclear whether these vowels are phonemes in this dialect so that the Ethiopian Eastern Jikany has 16 vowels. It is possible that there are 14 vowels and [u,ṳ] and [ɛ,ɛ̤] are allophonic. She reports eight diphthongs which are contrastive.

(1) Vowel inventory in Nuer in IPA (Reid, 2019)

a. Monophthongs :
/ɪ, i̤, e, e̤, ɛ, a, a̤, ɐ̤, ɔ, ɔ̤, o, o̤, ʊ, ṳ/

b. Diphthongs:
/ɪɛ, i̤e̤, ɛa, e̤a̤, ɔa, ɔ̤a̤, ʊɔ, ṳo̤/

In more detail, the diphthong /ɛa/ in (1) is not found in this study. Instead, the final part of this diphthong is more central; /ɛɐ̤/. For example the nominative singular form of ‘sheep’ *dɛ̂ˑl* changes to this diphthong in the oblique case of singular *dɛ̀ɐ̤ːl*. This would correspond to *dɛ̀aːl* in Lɔu Nuer. Similarly, the plural form of ‘dryness’ is *rɛ́ˑt̪*. In the singular, it changes to rɛ̀ɐ̤ːt̪.[4]

I follow Reid (p.c.) in using a morphological criterion for diphthong vs. semivowel transcriptions. When low back vowels are considered lexical, I transcribe them as a semivowel: /w/, as opposed to a vowel which is part of a diphthong. That is, when they precede a vowel in both the non-inflected form (nominative singular) and in all the inflected forms. When a low or high vowel appears only in some forms as part of an inflection, I transcribe it as a vowel. For example, the noun ‘gourd’ appears with the vowel /o̤/ in the nominative plural stem *tô̤ːk*. In the singular, it breaks into a diphthong *tûɔˑk* and is, therefore, transcribed with /uɔ/. In contrast, the noun ‘wild goose’ appears with /wɔ̤/ in the stem of all inflectional forms (combined with suffixes), *twɔ̤̄ˑt* NOM.SG, *twɔ̤̄ˑt-ní̤* NOM.PL. Therefore, these forms are transcribed with the semivowel /w/ as opposed to /uɔ/.

It appears that some of the diphthongs are disappearing in Ethiopian Jikany. For example, the noun lɔ̤́ːr NOM.SG *‘Acacia Seyal tree’* is written with a diphthong in the orthography – *luɔ̱r* – and changes to a /u/ in the oblique case: *lṳ́ˑr-ɐ̤̀* OBL.SG. The speakers of this study did not pronounce a diphthong in any of the forms: lɔ̤́ːr NOM.SG; lɔ̤́ˑr NOM.PL; and lɔ̤́ːr-ì̤ NOM.OBL. Similarly for ‘back’ ɟɔ̀*k*, its oblique form is written with a diphthong *jɔak*. In slow speech, some speakers would pronounce a short diphthong ɟɔ̀*ak*, but the majority of the speakers pronounced it with a monophthong ɟ*àk*. Another example concerns the diphthong /ɛ̤ɐ̤/. In some words, such as the noun *tɛ̤́ɐ̤ː* ‘secrets’, some speakers realize this diphthong as the vowel /æ/. This also indicates a possible loss of the diphthong /ɛ̤ɐ̤/.

[4] This means that the Ethiopian variant of Nuer does not strictly follow the vowel grade system proposed by Reid (2019) where /ɛ/ is considered a basic vowel which changes to a modified vowel by adding an /a/: /ɛa/.

Nuer has three degrees of vowel length. This typologically rare contrast has been shown for Nuer in Monich (2017), and has been solidly examined in the neighboring languages of Nuer, Dinka (Remijsen and Gilley, 2008) and Shilluk (Remijsen et al., 2018). The transcriptions used for this contrast is [V] for a short vowel; [Vˑ] for a mid-long vowel; and [Vː] for a long vowel. While a two-way length contrast is found in lexical minimal pairs, the three-way contrast has only appeared when one of the three vowel length contrasts marks an inflectional category.

There are only a few published studies on Nuer which involve tone. These studies are conflicting in their findings: According to Crazzolara (1933) there are a H, M, and L tone and six contour tones which combine these level tones. Similar claims are made by Yigezu (1995) with the difference that tonal realization depends on vowel length. That is, he claims that only long vowels carry a contour tone while short vowels carry a level tone. Storch (2005) acknowledges that tone is lexically and grammatically contrastive, however, she adds another parameter to tone by claiming that Nuer has stress. It is not clear how tone and stress go together in her account of Nuer. There is a recent study on tone in Nuer by Monich (Forthcoming). Her study and some of its differences to my proposal will be discussed in chapter 2.

1.1.2 Inflection

Inflection in Nuer is the part of the grammar where most of the fascinating tonal interactions happen. Inflection in Western Nilotic languages is complex because it involves many forms of non-linear exponence. The degree of complexity in Nuer is most probably due to a loss of affixes. As reported by Andersen (1990), lengthening of the stem in inflection often signals the loss of an affix when comparing the forms to neighboring languages. Baerman (2013) argues that this is also the case in Nuer. Comparisons with neighboring languages show that overlong stems are found in nouns which have a suffix in neighboring languages. The loss of suffixes might, therefore, have contributed to the particularly rich morphological marking in Nuer where stem-internal modification *and* suffixation are exponents in inflection marking.

Besides the abundant ways of stem-internal modifications in Nuer, nominal morphology displays a high irregularity of suffix distribution in number and case marking. The study by Frank (1999) shows that Nuer has nominative, genitive, and locative case. Different kinds of stem-internal alternations can mark case and number categories. These processes can either mark inflection alone or combine with suffixation. Suffixation is a productive process of marking inflection in Nuer. The area perhaps most subject to discussion has been the distributional complexity of the singular suffix *-kɛ̤* and the plural suffix *-ni̤* (Baerman, 2012). These suffixes show a high degree of irregularity.

To use the definitions of Pinker (1998), ‘regular morphology’ is an open class in which loan words and newly coined words enter, and such words are completely predictable. An example of regular inflection in English is the past inflection of verbs where the suffix *-d* is attached to stem. The phonology changes this ending depending on the stem ([t], [d], or [ɨd]), but these alternations are phonologically predictable and relate to the underlying morpheme; /d/ (Pinker and Prince, 1988). An example of irregular morphology in English would be the closed class of verbs with idiosyncratic past tense forms such as *sink-sank, go-went*.

Some examples of the nominal paradigm in Frank (1999) are shown in Table 1.4 below. The nominative form is considered the base form and genitive and locative singular is formed by suffixing *-kɐ̤* (orthographic transcription: *-kä*) to the nouns without any other changes to the stems. Genitive and locative plural are formed by suffixing *-ni̤* (orthographic transcription: *ni̲*).[5] In Table 1.4, the noun ‘banana’ has completely regular suffixation according to Frank because *-ni̲* applies in every plural form, and *-kä* appears in every singular non-nominative form.

The regular pattern was also used with nonce words in the genitive and locative of singular and plural forms in Frank (1999). This indicates that suffixation of *-kɐ̤* and *-ni̤* is productive in Nuer. However, this regular pattern appears very rarely in his data. Mostly, nouns have patterns like the following. In ‘nightmare’, the genitive and locative plural get vowel lengthening in the stems in addition to suffixes. The plural suffixes are realized as the allomorph -i̲ which appears after the liquids /r/ and /l/. The nominative plural only gets vowel lengthening. In the singular, *-kä* only appears in the locative, while genitive singular is segmentally unmarked. It is puzzling that the nominative plural is formed with vowel lengthening in the stem, but the genitive singular, which also lacks a suffix, does not lengthen. In comparison, the noun ‘milk’ is mostly formed with vowel lengthening and vowel modification. Only the locative plural has the suffix *-ni̲*. The stem also becomes breathy (ca̲k-ni̲). The noun ‘bear’ is similar to ‘nightmare’ by having *-ni̲* in only the genitive and locative plural, but the singular forms lack the suffix *-kä*.

Gloss	‘banana’	‘nightmare’	‘milk’	‘bear’
NOM SG	bɛle	pa̲r	cak	lɛt
NOM PL	bɛle-ni̲	pa̲a̲r	ca̲k	leet
GEN SG	bɛle-kä	pa̲r	caak	lɛt
GEN PL	bɛle-ni̲	pa̲a̲r-i̲	ca̲k	leet-ni̲
LOC SG	bɛle-kä	pär-kä	caak	lɛt
LOC PL	bɛle-ni̲	pa̲a̲r-i̲	ca̲k-ni̲	leet-ni̲

Table 1.4: Examples from suffix distribution in Nuer inflection taken from Frank (1999).

The forms in Table 1.4 are just a few examples of the possible combinations of the two suffixes which are reported for Nuer. Baerman (2012) finds that the suffixation patterns in the nominative, locative and genitive of singular and plural result in 24 different inflection classes. The regular pattern was only found in 22 out of 252 nouns that Frank collected and are a minority in Nuer. This means that the irregular nouns are the majority. The rest of Frank’s collected nouns were unpredictable in at least one of the six forms regular form of Table 1.4. One of the irregularities reported was that the genitive and locative singular forms did not always coincide,

[5] In Frank (1999), underlined vowels correspond to breathy vowels, two vowels correspond to a long vowel, and ’ny’ corresponds to /ɲ/.

and in 20% of the nouns, they had different forms. Although there are only a singular and a plural suffix, the possible combinations of these in the paradigm are so abundant that Baerman and Corbett (2009) have noted 16 different paradigm types. The possible combinations are shown in figure 1.1.

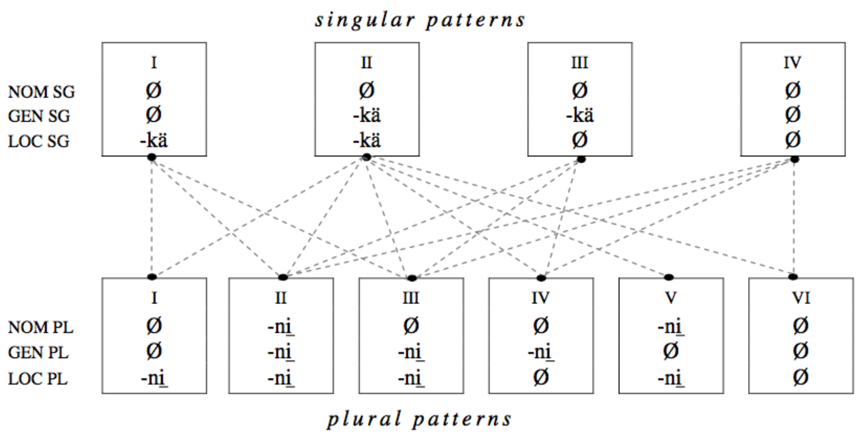


Figure 1.1: Figure taken from Baerman and Corbett (2009); SG–PL mappings in Nuer based on Frank (1999).

Regarding tone, Frank (1999) reports that he did not find compelling evidence for phonemic tone in Nuer and that there were no minimal tonal pairs in the collected items. Comparisons between Frank and this study will be presented in section 7.2.

1.1.3 Case constructions and word order

Case marking in Nuer involves dependent marking on the nouns. What I will refer to as oblique case are forms which appear in genitive constructions marking a possessive relationship between two nouns: the possessum noun appears first and is unmarked, i.e., in the nominative case, while the possessor noun follows and is marked for oblique case. This is shown in (3) below. The oblique forms also appear in locative constructions following a preposition as in (4). In these examples, the nominative form *rɔ̤́ˑt̪* in (2) changes to *rɔ̤a̤ːt̪* in both the possessive and locative constructions. The changes in tone for these forms will be discussed in the next section, and in chapter 7 in detail.[6]

[6]The word *gékɛ̤̀* in (4c) appears to be a lexicalized form of *gék* 'side' with the oblique singular suffix -*kɛ̤*. When the stem and suffix are combined, this word takes a possessor noun and means 'nearby' or 'around'. I represent the underlying tone of ɛ̤̀ as L because it is lexicalized.

(2) *Nominative*
rɔ̤́ˑt̪
'armpit'

(3) *Oblique with possessives*
a. míɛˑm rɔ̤̀a̤ːt̪
hair armpit\OBL
'the hair of the armpit'
b. cɔ̤̀a̤ː ↓rɔ̤́a̤ːt̪
bone armpit\OBL
'the bone of the armpit'

(4) *Oblique with prepositions*
a. wíˑ rɔ̤̀a̤ːt̪
at armpit\OBL
'at the armpit'
b. gék rɔ̤̀a̤ːt̪
side armpit\OBL
'around the armpit'
c. gékɛ̤̀ ↓rɔ̤́a̤ːt̪
edge armpit\OBL
'around the armpit'
d. rɛ̂ˑj rɔ̤̀a̤ːt̪
inside armpit\OBL
'inside the armpit'

The oblique form appears in other constructions as well. In (5a), the person-inflected particle *t-êˑ* precedes a noun in the nominative.[7] The meaning which arises is '(s)he has a house.' If the noun is inflected in the oblique case as in (5b), a locative meaning arises '(s)he is in the house.' The latter form of the noun is the same as in a possessive construction (5c). However, some nouns have a segmentally different form in the oblique case and the form after *t-êˑ* with a locative meaning.

(5) a. t-êˑ dúe̤l
exist-3SG house
'(S)he has a house.'
b. t-êˑ dùe̤ːl
exist-3SG house\OBL
'(S)he is in the house.'
c. t̪ḭ́ˑk dùe̤ːl
door house\OBL
'the door of the house'

In constructions marking possession with a pronoun, nouns are head-marked and take a number index: *-d* (singular) or *-k* (plural), and a person index attaches to the noun.[8] This is shown in (6)–(7). Note that the consonants *-d* and *-k* are elided after liquids in these pronouns. For convenience, they are not separated by a hyphen in the examples. The tonal patterns in these constructions reveal the underlying tonal specification of the stems and will be discussed in chapter 7.

[7] Note that the person suffix of the third person singular which attaches to verbs and nouns is -ɛ. Morphologically, it appears to be the same suffix in the particle *t-êˑ*, and it is transcribed as such. However, the speakers pronounce it with a closed vowel /e/.

[8] These person indices have properties of both clitics and suffixes. Therefore, they are simply referred to as 'possessive markers' (see Faust and Grossman 2015).

(6) *Possession marking singular*

a. rɔ̤́ˑt̪-dɛ̤́
armpit-POSS.SG:1SG
'my armpit'

b. rɔ̤́ˑt̪-dɛ̀
armpit-POSS.SG:3SG
'her/his armpit'

(7) *Possession marking plural*

a. rɔ̤́a̤ːt̪-kɛ̤́
armpit-POSS.PL:1SG
'my armpits'

b. rɔ̤́a̤ːt̪-kɛ̀
armpit-POSS.PL:3SG
'his/her armpits'

Nuer has SVO order when the verb is in the imperfective. In other aspects, where an auxiliary is used, the object appears before the verbal stem (cf. Faust and Grossman, 2015). The former is shown in (8) and the latter is given in (9) below. The constructions in (9) are interesting regarding tonal restrictions. As chapter 5 and 6 will show, there is a L tone restriction in Nuer. This is repaired by the insertion of a H tone. The L tone restriction is active between the noun and the verbal stem. That is, the H tone insertion appears on L tone verbs following L tone nouns in similar constructions to (9).

(8) SVO

a. gwìc-ɛ̤́ bâˑr
look-1SG lake
'I am looking at the lake.'

b. càm-ɛ̤́ lòɲ
eat-1SG lion
'I am eating the lion.'

(9) S AUX O V

a. bì-kɛ́n bâˑr nɛ̀ˑn
FUT-3PL lake see
'They will see the lake.'

b. c-ɛ̀ lòɲ câm
PFV-3SG lion eat
'(S)he has eaten the lion.'

1.2 Data collection

The data presented in this dissertation result from elicitations over several periods between 2016–2017. A part of the data was collected during a field trip to Addis Abeba in May and June 2017. Other elicitations were conducted in Israel, Leipzig, and Oslo with durations of 1–2 weeks for each visit. Besides the 32 consultants who participated in the phonetic studies, I have worked with seven main consultants. They are native speakers of the Eastern Jikany dialect of Nuer: six males and one female; aged 26–42. These consultants come from either Gambela town or the rural area of Gambela at the Ethiopian border to South Sudan. The exception is one consultant, who was born in Nasir in South Sudan and came to Gambela when he was seven years old. All consultants are speakers of Eastern Jikany and come from the Gajaak and Gajiök tribes.[9] Five of the consultants live in Addis Abeba and speak Amharic and English as foreign languages; one consultant lives in Oslo and speaks Norwegian and English as foreign languages; and one consultant lives in Israel and speaks Hebrew and English as foreign languages. The

[9] See section 1.1 for information on the geographical distribution of these tribes.

speakers use Nuer on a daily basis and visit Gambela regularly.

The elicitations were conducted in English. A typical session involved transcription of data relying on my ears followed by recordings of the transcriptions. The data were verified by at least two speakers for the phonological material. The recordings were made using an H5 Zoom recorder with an external microphone: a SM10A dynamic head-worn microphone. An AKG C1000S cardioid condenser microphone was also used on a few occasions. The sampling rate of the recordings was 44.1 kHz with 16-bit quantization and a mono wav-sound file inscription.

The analysis presented in this dissertation is mainly based on nominal paradigms of 80 nouns (68 native words and 12 loan words) and partly on verbal paradigms. The nouns were recorded in the nominative, locative and genitive constructions of singular and plural nouns. Many different grammatical contexts and sentence-positions were tested and recorded with the nouns to check for lexical tone, sandhi effects, and grammatical tone.

1.3 Empirical findings on lexical tones

On a broad scale, the empirical goal of this dissertation consisted in finding phonological and phonetic evidence of tonal contrast in Nuer nouns. Regarding phonetic evidence of these tones, I examined the f_0 production and perception of native Nuer speakers for lexical tone. In this section, I present a synopsis of these findings.

Tonal contrasts The collected data which are presented in chapter 2 indicate that tone is contrastive on the syllable level. Minimal pairs robustly contrast between H and L tones and between L and HL tones. In comparison, minimal pairs of H and HL tones are rarer, but there are near minimal pairs of these tones. On the surface, there are a small number of nouns with a mid tone (9 nouns in total). They alternate with a rising tone in sentence-initial position.[10]

Moreover, breathy vowels are only found with level tones, while modal vowels appear unrestricted with all tones. I claim this is an epiphenomenon of grammatical tone. As I show in chapter 7, plural number is marked by H tones, and most plural stems appear with a breathy stem. Thus, plurals tend to be H-toned and breathy.

Production of tone In speaker's production, H and L tones are expected to contrast in f_0 in that a H tone is realized with a high-pitched note, and a L tone with a low-pitched note. HL tones fall from a high-pitched note to a low-pitched note. Concretely, they are expected to contrast in midpoint: high f_0 for H tones, low f_0 for L tones, and a f_0 value in the middle for HL tones. The latter is expected because, at the midpoint of the vowel, the contour has traveled halfway from H target towards its L target. As chapter 3 shows, these tonal distinctions were clearly realized phonetically in Nuer. The instrumental studies of f_0 in chapter 3 show a significant contrast in the midpoint of H-, HL- and L-toned nuclei: H tones have a mean value of 9.5 semitones

[10] I consider them lexical with an underlying tone and a floating tone which create a surface mid tone. I am agnostic to whether this involves a H tone with a floating L tone, or a L tone with a floating H tone – see section 10.2.2 for a discussion.

(ST), while L tones have a mean value of 5.6 ST (3.9 ST difference). The midpoint of HL-toned nouns corresponds to a value which lies approximately in the middle of the H and L tones (7.8 ST). Additional measurements were done on a M-toned noun. In three sentence types, it was realized in the middle range between the H and L tone without overlaps.

The tones are also expected to contrast in slope, i.e., the upward or downward glide between the beginning and the end of a tonal target. H and L tones are expected to have a relatively flat slope, while HL tones are expected to have a falling slope. This was confirmed in that HL tones had the biggest slope regardless of the contexts they were pronounced in.

Concerning prosodic effects of tones, the instrumental results indicated a 'final lowering': a decrease in f_0 which affects the final part of the nucleus utterance-finally. Final lowering in Nuer increases the slope of the tones, and L tones were most prominently affected. This makes them similar to HL tones in an utterance-final position. When HL and L tones are pronounced utterance-finally following a H target, the average slope hardly differs (3.1 ST vs. 2.7 ST respectively). The main difference lies in the timing of the fall. The f_0 of L tones starts to drop already at the onset of the target word, while for the HL tones, it starts to drop later at the vowel onset.

Perception Chapter 4 tests the similarities of perception between HL and L tones which were found in the production. This is done by manipulating the f_0 peaks by alignment and height of minimal pairs differing in these tones. A phonological contrast is expected to have acoustic correlates in both the production and perception of f_0. The goal of the perceptual study was, therefore, to test the identification of these two tones because they showed the most overlap in the production. If HL and L tones have an underlying contrast, it is expected that listeners perceive these differences. A clear perceptual distinction indicates an active role of perceptual cues in the phonological contrast of tone (see D'Imperio 2000 for a discussion of this). Hence, the goal was to examine whether there is any ambiguity between these tones, or whether listeners perceive a clear contrast.

Both experiments in f_0 height and alignment involved a forced-choice identification task where listeners had to choose between the meaning corresponding to the HL items or the L items. In the f_0 height experiment, the f_0 of minimal pairs of HL and L tones in isolation was manipulated from 0–5 ST. The results show that tones which have a f_0 peak around 2 ST and below are perceived as L-toned, while tones with a peak at 3 ST and up to 5 ST are perceived as HL. There is an ambiguity in the perception of these two tones when the peak is between 2–3 ST. The importance of these findings is, first of all, related to tonal realization in Nuer. The results show that listeners employ f_0 height to separate a L tone from a HL tone. This supports the observation from the production study that Nuer has final lowering. As mentioned, final lowering creates a falling contour on L tones. The perception responses show that this fall is phonetic because even when L tones have a peak of 2 ST, they are still perceived as L. That is, they do not have to be realized as level tones to be perceived as L. Second, the findings are interesting cross-linguistically. The responses show that as little as 1.2 semitone can separate a HL tone from a L tone in isolation. This differs from the highly cited work by 't Hart (1981) who found that 3.2 ST is the minimal difference needed to perceive a tone change in speech. Newer studies vary regarding the predictions of differential threshold in perceived pitch differences. Thus, the results of this study provide insight into how many semitones are needed in speech communication in a language where tone contrasts at the syllable level.

The results of the experiment on f_0 alignment are even more interesting and will be explained in more detail. The tested stimuli for this experiment were minimal pairs of HL and L tones following a H tone target. As was observed in the production study, the difference between the tones in this utterance-final position lies mainly in the alignment, i.e., the location of the peak in relation to speech segments. To give a brief background, it has been shown that the perception of tonal alignment can be contrastive for intonation at the utterance level but this is not as well studied in the syllable domain. In a syllable, the vowel is the perceptually salient part. Therefore, if a f_0 drop from H to L takes place here, it is perceived as a falling tone. If the fall takes place at the onset, the f_0 drop takes place in a non-salient part of the syllable where it is not easily perceived. Once the f_0 contour has reached the vowel, it is at a low point and is perceived as a L tone.

Stimuli of three different minimal pairs were manipulated in f_0 alignment starting from the late alignment of 30 ms into the vowel (a HL contour) and incrementing backward by 15 ms steps until the peak is −120 ms distanced from the onset-nucleus boundary. Here the peak is located in the coda of the previous H tone target and the noun corresponds to a L tone. This experiment has a number of important implications. First, the results confirm that Nuer listeners have a binary perception of HL vs. L tones. Second, there is a point in the onset where the f_0 peak needs to be located to obtain the perception of a H#HL sequence as opposed to a H#L. For H#HL perception, short vowels require that the f_0 fall start to drop near the edge of the vowel. For long vowels, H#HL perception is obtained even when the drop is located in the middle of the onset. The reason why this is possible in long vowels is that there is more time to hear the fall within the vowel. These results are surprising because they show that Nuer listeners can perceive f_0 movement across the onset-nucleus boundary, a region of spectral instability. According to the model of optimal tone perception by House (1990), tonal movement in this region is perceived as level.

A schematic representation of the findings of tonal alignment is presented in Figure 1.2 below. The contours show the locations of the f_0 alignment in the stimuli when HL tones were perceived (80%≥ HL responses), and where L tones were perceived (20%≤ HL responses). These points depend on whether the vowel is long or short. This figure illustrates the short vowels. The earliest point where a HL tone is perceived (dashed line) in relation to the nucleus is 15 ms to the left of the onset-nucleus boundary. From this point and rightwards, until the peak is located into the vowel, listeners perceive a HL tone. For the L tone, the latest time point where it was perceived was 32 ms to the left of the onset-nucleus boundary. The L tone perception increases up to almost 100% the further to the left the peak is aligned. The puzzling result is that the distance between the latest perceivable L point and the earliest perceivable HL point are extremely close. When the peaks are located between these points, there is ambiguity between a L and HL tone perception. Thus, a major finding here is that the period of ambiguity is only 16 ms for short vowels. That is, there is a critical region within the onset of the target word, where 16 ms in the manipulation can separate a L tone from a HL tone. The time of uncertainty increases with long vowels where it lies between 22–32 ms.

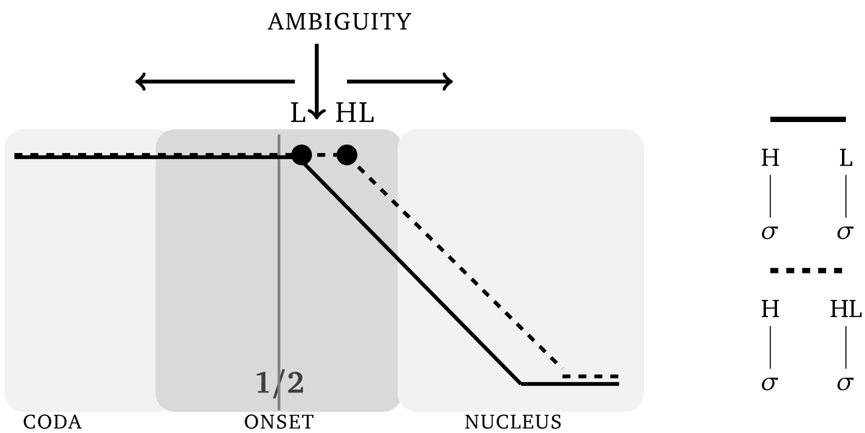


Figure 1.2: Schematic representations of alignment boundaries of HL and L tones on a short vowel after a H target based on perceptual responses. HL responses (dashed line) are obtained at earliest when the peak is aligned approximately 1/5 from the nucleus and rightwards into the vowel, while L tone responses (solid line) are obtained when the peak is aligned at almost 1/2 away from the nucleus (in the middle of the onset) and leftwards towards the coda (at the beginning of the onset). There is ambiguity when the alignment is between these points.

Compared to other studies on f_0 alignment, the time of uncertainty in Nuer radically stands out. Studies on this topic have mostly been done in languages with a restricted tonal inventory such as Mainland Scandinavian, English, German, and Italian (cf. Bruce 1977, 1983; Bruce and Gårding 1978; Kohler 1987; Pierrehumbert and Steele 1989; Verhoeven 1994; D'Imperio and House 1997; Kelly and Smiljanić 2017, among many others). Such studies have shown that listeners need much more time to hear a categorical shift between two tonal targets. On average, House (2004) notes that the observed time of uncertainty is around 50 ms. The degree of tone sensitivity in Nuer is a welcoming result for this study because it supports the claim I make on the prominence of tone in this language. It might be found surprising that listeners are sensitive to such small acoustic differences in tone, especially considering that most native speakers are not aware of Nuer being a tone language. While they are aware of vowel length differences and distinctions of vowel quality and phonation, speakers do not count tone in their language awareness. Second, there are many parameters for stem-internal modifications. Therefore, tone has previously been neglected or assumed to play only a secondary role. This study shows that tone does play a primary role in Nuer.

In sum, the experimental studies support the claim of a phonological contrast between H, L, and HL tones in Nuer. The results of both perception experiments show that Nuer listeners employ f_0 height and alignment as cues for distinguishing a HL from a L tone and that the distinction between HL vs. L tones is binary and not gradient. An overview of the findings on lexical tones is given below in (10).

(10) **Findings on the representation and realization of lexical tones**

a. Minimal pairs indicate an underlying contrast between H, L, and HL tones
b. H, L, and HL tones contrast phonetically in slope and midpoint
c. Nuer has final lowering which increases the slope of L tones
d. HL tones are perceived when:
   (i) the peak is above 2 ST (in isolation)
   (ii) the peak is located at least 50% into the onset for long vowels, and at least 80% into the onset for short vowels
e. Sentence-final HL and L tones show a clear contrast in the listener's perceptual space:
   (i) 1.1–1.5 ST in f_0 height can distinguish a HL from a L tone
   (ii) 16–32 ms in f_0 peak alignment can distinguish a HL tone from a L tone
   → Cross-linguistically, Nuer listeners prove to be sensitive to remarkable small-scaled differences in manipulations of f_0 height and alignment

1.4 Findings on adjacent L tones

After establishing that H, L, and HL tones contrast lexically, the next relevant research question is how they differ in relation to phonological restrictions. The findings of the next part of this dissertation establish that there is a restriction against adjacent L tones in Nuer known as the Obligatory Contour Principle (OCP). When underlying L tones occur in adjacent positions, they surface with a downstepped H tone. This is a notable finding because typologically, the OCP does not often apply to L tones. I refer to the process which repairs the OCP-L violation as H tone epenthesis.

H tone epenthesis reveals a difference in the nouns. 'unstable' nouns have a floating lexical tone. H tone epenthesis targets their stem, and the nouns surface with a downstepped H tone (11). In comparison, there are so-called 'stable' nouns which have an underlying tone and are immune to H tone epenthesis in certain prosodic positions. In these instances, the H tone targets adjacent syllables even if this leads to an inefficient repair of the L tones (12). A HL tone also appears on the verbal stems. This HL tone can also be observed in the other examples below. Here, H tone epenthesis targets a L-toned infinitive stem which follows a L-toned noun creating a falling tone (13). If it follows a H-toned noun or a HL-toned noun, the verb remains L-toned (14)–(15).

Contexts with OCP-L violations

Unstable L tones

(11) /c-ɛ̀ ᴸmaːr nɛ̀ˑn/
c-ɛ̀ ꜜmáːr nɛ̂ˑn
PFV-3SG relationship see
'(S)he has seen the relationship.'

Stable L noun

(12) /c-ɛ̀ kɛ̤̀ːr nɛ̀ˑn/
ꜜc-ɛ́ˑ kɛ̤̀ːr nɛ̂ˑn
PFV-3SG line see
'(S)he has seen the line.'

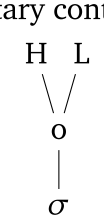
(13) /cì-kɔ̄n ᴸloŋ nɛ̀ˑn/
cì-kɔ̄n lòŋ nɛ̂ˑn
PVF-3PL lion see
'We have seen the lion.'

(14) cì-kɔ̄n mɔ́n nɛ̀ˑn
PVF-3PL soil\PL see
'We have seen soils.'

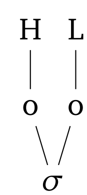
(15) cì-kɔ̄n wâːr nɛ̀ˑn
PVF-3PL sheep.dung see
'We have seen sheep dung.'

The L tone restriction reveals properties of the HL tones. As shown in the examples above, this restriction applies only in L(#)L sequences while HL(#)L sequences are tolerated. In the autosegmental approach to tone by Goldsmith (1976), contour tones are modeled as a sequence of two tones linked to one unit. This assumption predicts that a HL syllable and a L syllable should trigger the same tonal processes because at the tonal tier, they both end in a L tone. Since this does not apply in the data, it suggests that lexical HL tones in Nuer are not a sequence of a H and a L tone. Instead, I claim that they are a unitary contour tone (Yip, 1989, 1990) with the structure shown in (16). The alternative structure where contour tones are a cluster of two level tones is given in (17). The verbal stem *nɛ̂ˑn* with the derived contour tone in the examples above is assumed to have this type of cluster contour tone.

Unitary contour tone

(16) 

Cluster contour tone

(17) 

Yip (1989) argues that unitary contour tones are characteristic of East Asian tone languages. The structure in (17), which I claim only appear as derived tones in Nuer, is more common in many African tone languages. The canonical stem in Bantu nouns is disyllabic with a sequence of two level tones, and contour tones typically arise as a consequence of vowel deletion or tone spreading and are often restricted to long vowels. Overall, I argue that Nuer has more properties in common with East Asian tone languages than with African tone languages such as Bantu. Nuer is a monosyllabic language where the contour tones observed on nouns are underlying and can appear on short vowels. Derived tones such as *nɛ̂·n* are rare and only found in utterance-final positions.

The results of the instrumental study in chapter 6 confirm the realizations of H tone epenthesis on the verb in the configuration in (13). The configurations in (14) and (15) showed no H tone epenthesis. All three contexts were tested with 30 nouns. The f_0 midpoint and slope on the verb following either H, L, or HL nouns were measured. The verb shows a significant difference depending on the tonal specification of the noun it follows. After a H or a HL noun, the f_0 values support a L tone on the verb as shown in (14) and (15). In sentences such as (13), the verbal stem surfaces with a slope and midpoint of f_0 which corresponds to a HL tone. It is an essential finding that only L-toned nouns, and not HL-toned, nouns trigger H tone epenthesis on a following L tone.

To conclude this section, H tone epenthesis targets nouns differently depending on their underlying tone. Stable nouns have an underlying L tone which cannot be overwritten while unstable nouns have a floating lexical tone. Unstable nouns have a floating L tone in the input, and when it appears with adjacent L tones, it surfaces as a downstepped H tone. The empirical finding shows that L(#)L sequences in Nuer are illicit, while HL(#)L sequences are not. This supports the structure of HL tones in such constructions as a melodic unit rather than a cluster of two tones on one syllable. The findings of H tone epenthesis is summarized in (18) below.

(18) **Findings on the representation and realization of adjacent L tones**

a. Adjacent L tones are illicit in the word and phrase domain with nouns (OCP-L)
b. H tone epenthesis repairs OCP-L. Its application reveals underlying tones:
   (i) Unstable L nouns surface as [$^{\downarrow}$H] because they have a floating lexical tone
   (ii) Stable L nouns remain L and adjacent syllables are targeted instead
c. Instrumental studies show the realization of H tone epenthesis on the verb stem: an underlying /L#L/ sequence between two words surface as [L#HL], whereas /H#L/ and /HL#L/ do not change
d. The failure of /HL#L/ to trigger OCP-L violations indicate that HL tones have a unitary structure

1.5 Synopsis of proposal

Tone in Nuer becomes increasingly fascinating when considering its function in nominal inflection. The final part of this dissertation shows the interactions of nominal tone in this area of the grammar. This study give evidence for a serial interaction between lexical tone, H tone epenthesis, and inflectional tone. The analysis relies on two core ideas. The first regards the representation of tone, and the second regards the organization of the grammar. The main ideas concerning the representation of tone are given first. I propose that the apparently chaotic inflection patterns in Nuer are due to a bidirectional defectiveness. Here, defectiveness refers to underspecification of features, such as tones, or prosodic structure, such as a (tonal) root node, but also cases where segmental material is missing (e.g., an affix consisting only of a floating tone). More specifically, I claim that non-concatenative morpho-phonology in Nuer can be explained by defective material in stems interacting with defective material of affixes. This approach can be seen as an extension of the *Generalized Non-linear Affixation* (GNLA), a research program proposed by Bermúdez-Otero (2012) where defective affix material accounts for non-concatenative morphology. I show that a bidirectional approach to GNLA is needed to account for the data. A summary of this type of defectiveness is given below.

In section 1.1, a brief background was given on the suffixation patterns in nominal inflection. According to Baerman (2012: 470), there are 24 inflection classes in Nuer nouns. An important outcome of the data collection in this dissertation is a drastic reduction of inflection classes from 24 to five, when considering the distribution of the suffixes *-kḛ* and *-nḭ*, as shown in Table 1.5. The class reduction is partly due to the fact that the locative and genitive case are collapsed into the oblique case. The other reason is that there is generally a higher regularity in the inflection with less alternative forms for each category. Note that even with the syncretism of the genitive and locative case, an additional four classes with different suffix patterns would theoretically be possible but are not found in this study.

In the previous section, the stable – unstable stem division was outlined concerning H tone epenthesis. It turns out that this distinction plays an even more prominent role in inflection. A remarkable outcome is that when tone comes into play, the new suffixation patterns reveal a three-way contrast in underlying stem tones: Stable, unstable and hybrid nouns. I claim that these stem distinctions can replace inflection classes of suffixation entirely.

CL	NOM SG	OBL SG	NOM PL	OBL PL	
I	Ø	-kḛ	-nḭ	-nḭ	Stable stems
II	Ø	**Ø**	-nḭ	-nḭ	
III	Ø	-kḛ	**Ø**	-nḭ	Hybrid stems
IV	Ø	**Ø**	**Ø**	-nḭ	Unstable stems
V	Ø	**Ø**	**Ø**	**Ø**	

Table 1.5: Classification for inflection classes based on suffix pattern and tone. The bolded marked '**Ø**' indicates stem-internal modifications.

I propose a three-way defectiveness of the stems, as represented in (19). Stable stems bear a lexical tone which is linked to the stem via a root node. Hybrid and unstable stems are not linked to tones in the input. The former ones feature a lexical tone associated with a root node which is floating. I will refer to these as a tonal tree. The latter ones have an extra degree of defectiveness. They have a lexical tone which lacks a root node. I will refer to these as simply (floating) tones. The existence of root nodes are independently needed for the structure of HL tones – see section 1.4.

(19) Proposed structural differences for nominal stems

Stable stem	Hybrid stem	Unstable stem
(a linked tone)	(a floating tonal tree)	(a floating tone)
T	T	T
|	|	
o	o	
|		
σ	σ	σ

Besides suffixation, I claim that tones in Nuer mark number and case: a H tonal tree marks plural while a L tonal tree marks oblique case. Their structure correspond to the tone shown in the hybrid stem in (19) above. Segmentally, *-ni̤* marks the plural and *-kę̤* marks the singular. The exponents of inflection are listed in Table 1.6. The proposal is that these exponents are defective because the suffixes are toneless, and the tonal trees lack a segment. Instead of occurring together as a *-ní̤* and *-kę̤̀*, they are defective by appearing separately on different strata in the grammar: the stem, word, and phrase levels. The H tonal tree has a HL tonal tree allomorph which appears with some stems. All stem types are subject to the exponents in Table 1.6 but at different levels in the stratal evaluation. Ranked constraints evaluate a set of candidates and the inputs differ regarding the tonal structure of the stems. These representational differences have a crucial outcome for whether a suffix combined with a stem gets a surface tone and survives in the output, or whether it does not get a tone and is deleted in the output. This approach allows number and case markers to appear systematically on the three different strata, and it depends on the constraint rankings and the different inputs whether and how this material surfaces.

	Level	Tonal exponents	Suffixation	
i.	Stem:	H(L) tonal tree$_{[\text{PL}]}$	Ø	Nominative case
ii.	Word:	Ø	-ni̤$_{[\text{PL}]}$	Nominative case
iii.	Phrase:	L tonal tree$_{[\text{OBLIQUE CASE}]}$	-kę̤$_{[\text{SG}]}$	Oblique case

Table 1.6: Tonal and suffixal exponence of case and number in Nuer.

By looking at floating tones, the stem distinctions can now be observed with both H tone epenthesis (consisting of a floating H tone) and inflection exponence. Consider the data below.

They show that nouns pattern uniformly concerning whether the stems (i) take a suffix or link with the tonal tree in the oblique case and (ii) are subject to H tone epenthesis or not. The stable nouns take a suffix in the oblique case as shown in (20) and (21). The suffix *-kɐ̤* attaches to the stem and links to the L tonal tree (20). Because of OCP-L, the suffix gets a H tone if the stem is L-toned (21). When L tone sequences appear as in (21b), the possessum noun gets H tone epenthesis: /c̤ɔ̤̀a̤ː gwàk-ɐ̤/ surfaces as [↓c̤ɔ̤́a̤ː gwàk-ɐ̤́]. The downstep is a result of the L tone of *c̤ɔ̤̀a̤ː* which gets delinked. Thus, the stem tone of *gwàk* is always stable while the suffix changes its surface tone.

The opposite pattern can be observed in (22). This is an unstable noun with a floating tone in the input /ᴴr̤ɔ̤ˑt̪/which does not get a suffix in the oblique singular. Instead, the L tonal tree links to the stem tone. The H tone in *r̤ɔ̤́ˑt̪* 'armpit' surfaces with a L tone in the oblique case (22a). In sequences with adjacent L tones, H tone epenthesis targets the stem of the possessor noun instead of the possessum noun. The example in (22b) shows that when it follows the L-toned possessum noun *c̤ɔ̤̀a̤ː*, H tone epenthesis applies to 'armpit'. It gets a downstep from the oblique L tonal tree, which delinks from its root node: [c̤ɔ̤̀a̤ː ↓r̤ɔ̤́a̤ːt̪]. In other words, the stem tone of such nouns is unstable in the sense that floating tones can freely link to them. In relation to inflection and H tone epenthesis, they are the mirror image of stable nouns behaving similarly to toneless suffixes.

Stable nouns

- A L tonal tree links to suffix in the oblique case
- H tone epenthesis on the possessum noun

Unstable nouns

- A L tonal tree overwrites stem in the oblique case (no suffixation)
- H tone epenthesis on the possessor noun

(20) Nominative: gá̤ˑc
bîɛl gá̤ˑj-kɐ̤̀
color belt-OBL.SG
'the color of the belt'

(21) Nominative: gwàk, c̤ɔ̤̀a̤ː

a. ɟɔ̂ˑ gwàk-ɐ̤́
behind fox-OBL.SG
'behind the fox'

b. ↓c̤ɔ̤́a̤ː gwàk-ɐ̤́
bone fox-OBL.SG
'the bone of the fox'

(22) Nominative: r̤ɔ̤́ˑt̪

a. rɛ̂ˑj r̤ɔ̤̀a̤ːt̪
inside armpit\OBL
'inside the armpit'

b. c̤ɔ̤̀a̤ː ↓r̤ɔ̤́a̤ːt̪
bone armpit\OBL
'the bone the armpit'

The stable – unstable distinction can derive most of the data. It is for plural forms that the hybrid stem distinction is needed because a similar pattern to the oblique case arises in the plural. The H tonal tree which marks plural either associates to the stem, as in *r̤ɛ̤̀ɐ̤ːt̪* 'dryness' → *r̤ɛ̤́ˑt̪* 'drynesses' or on the suffix *-n̤i̤*, as in *kɛ̤̀ːr* 'line' → *kɛ̤̀ˑr-í̤* 'lines'. I argue that also this difference relates to the nature of the stem tone. Hybrid nouns like 'dryness' have some properties of the unstable nouns and some properties of stable nouns. On the one hand, they are unstable because the plural H tonal tree links to their stem instead of a suffix in the nominative. On the other hand, they are stable because they do get a suffix in the oblique singular (*rɛ̀ˑt̪-kɛ̤́*), and their stems are not subject to H tone epenthesis. The hybrid stem type captures this by having have more structure than the unstable stems, i.e., a tonal tree floating in the input. Table 1.7 gives an overview of the three-way stem distinction. In the singular, a two-way contrast shows up: stable vs. unstable, while stable nouns contrast with hybrid nouns in the plural.

	SINGULAR		
	Oblique exponence		Target of H tone epenthesis
Stem type	Suffixation (-kɛ̤)	L tonal tree on stem	
Stable nouns	✓	✗	✗
Hybrid nouns	✓	✗	✗
Unstable nouns	✗	✓	✓
	PLURAL		
	Nominative exponence		
	Suffixation (-n̤i̤)	H(L) tonal tree on stem	
Stable nouns	✓	✗	✗
Hybrid nouns	✗	✓	✗

Table 1.7: Stem contrasts in inflection and H tone epenthesis. In the singular, there is a two-way contrast between stable and unstable nouns. Stable nouns contrast with hybrid nouns in plural exponence.

The second component of the analysis regards the serial organization of the morpho-phonology. I claim that the main surface forms in inflection can be accounted for if the case and number exponents appear at different strata in the grammar. Instead of inflection classes, phonological operations account for the suffix distribution. In a nutshell, all stems get a suffix in the plural and the oblique case. Singular forms get *-kɛ̤* in the oblique case while plural stems receive the suffix *-n̤i̤*. It depends on the nature of the stem tone whether the suffix will actually surface or not. This plays out in Stratal OT. There are three strata: stem, word, and phrase level. At the stem level, plural nouns get the H tonal tree floating in the input. At the word level, they get the suffix *-n̤i̤*. Singular stems have no exponents at these levels. At the phrase level, the L tonal tree appears in the input for both singular and plural stems, and the singular gets the suffix *-kɛ̤*.

Table 1.8 shows the serial derivation of plural stems in the oblique case. At the stem level, the input has a lexical tone and the H tonal tree marking plural. The stable stem is linked to the lexical tone in the input. The plural H tonal tree cannot link to the stable stem without violating high-ranked faithfulness constraints which work to preserve the stem tone. This is different for hybrid nouns because their lexical L tonal tree is floating in the input, and they are free to link to the H tonal tree. At the word level, the segmental exponent of plural number appears: the toneless suffix *-n̤i̤*. Floating tones are preserved across the strata. This means that the plural H tonal tree which could not link to the stable stem in the previous stratum can now link to the suffix. The result is a L-H pattern for this stable noun. Syllables in Nuer generally want a surface tone in the output. However, for the hybrid nouns, the suffix cannot get a tone without violating high-ranked constraints against tone insertion, association line crossing, or tone spreading. Therefore, the suffix remains toneless. At the phrase level, the L tonal tree of the oblique case appears. The input of the stable noun is already specified for tone. The L tonal tree remains floating because it cannot overwrite neither the stem nor the suffix. Hybrid nouns, on the other hand, now have a toneless suffix and the L tonal tree which is floating. The optimal output is an association between the L tonal tree and the suffix resulting in an oblique plural form with *-nì̤*.

<table>
<tr><th></th><th>Stable</th><th>Hybrid</th></tr>
<tr><td>Stem level Input
Plural H tonal tree</td><td>L H
| |
o o
|
σ</td><td>L H
| |
o o

σ</td></tr>
<tr><td>Stem level Output</td><td>L H
| |
o o
|
σ</td><td>L H
| |
o o
/
σ</td></tr>
<tr><td colspan="3">Word level Input -ni̤</td></tr>
<tr><td>Word level Output</td><td>L H
| |
o o
| ¦
σ -σ</td><td>L H
| |
o o
/
σ -σ</td></tr>
<tr><td>Phrase level Output</td><td>L H L
| | |
o o o
| |
(...) σ -σ</td><td>L H L
| | |
o o o
/ ¦
(...) σ -σ</td></tr>
</table>

Table 1.8: Overview of stratal derivations in the plural oblique form.

Table 1.9 shows the singular derivation for the oblique case. The nouns go through the same levels as the plurals, but the stem and word levels are vacuous these levels have no inflection exponence. Also, the stable nouns cannot be improved as their stems already have a linked tone, and the unstable nouns can also not be improved without violating a high-ranked constraint against insertion of a root node. The derivation goes as follows. The oblique exponents *-kɛ̤̀* and the L tonal tree appear at the phrase level. The rightmost columns show the H-toned stems. For the H-toned stable stem, this L tonal tree is free to link to the suffix. The output corresponds to e.g., the form *gá̤·j-kɛ̤̀* ‘of belt’ in (20).

For the H-toned unstable stem, the floating tonal tree can link to its stem because it comes with a root node. In fact, the oblique L tonal tree provides the necessary structure for the stem to receive a surface tone. However, this leaves a toneless suffix which cannot get a tone because the insertion of a root node violates high ranked constraints. The optimal output is a candidate which deletes the whole suffix leaving a L-toned monosyllabic oblique form as was seen for *r̤ɔ̤̀a̤ːt̪* 'of armpit' in (22a).

For the L-toned stems in the two left-most columns, H tone epenthesis applies because the possessum noun is L-toned (represented by a square bracket). For the stable stem, H tone epenthesis applies to both the suffix and the possessum noun. This unusual repair is captured by the fact that: (i) the suffix does not have a tone in the input, and consequently, H tone epenthesis on it is not violated by faithfulness constraints; (ii) there is a faithfulness constraint which protects the tone linked to the rightmost syllable of the p-phrase: the possessor noun. For this reason, the preference is to insert a H tone to the left and right of the possessor stem to avoid a [L#L-L] sequence. This kind of output was seen on *gwàk-ɛ̤́* in (21b). For the unstable noun, H tone epenthesis links to the stem tone of the possessor noun by 'borrowing' the root node of the oblique tonal tree. The unlinked L creates a downstep and the unstable noun surfaces with a ꜜH tone following the L-toned possessum. This kind of output was seen for *ꜜr̤ɔ̤́a̤ːt̪* 'of armpit' in (22b).

Level	Stable L	Unstable L	Stable H	Unstable H
Stem level input and output	L o σ	L σ	H o σ	H σ
Word level Ø	vacuous derivations			
Phrase level Input Oblique L tonal tree -*kɛ̤*	L L L o o o $\sigma]\sigma$ -σ	L L L o o $\sigma]\sigma$ -σ	HLH L o o o $\sigma]\sigma$ -σ	HLH L o o $\sigma]\sigma$ -σ
Phrase level Output	L H L L H o o o $\sigma]$ σ -σ	L L L H o o $\sigma]$ σ	H L H L o o o $\sigma]$ σ -σ	H L H L o o $\sigma]$ σ

Table 1.9: Overview of stratal derivations in the singular oblique form.

The presented proposal on the serial interaction of tone in Nuer shows that phonology can take the workload of irregular morphology. This is done by (i) enriching the tonal representation in nominal inflection with a bidirectional approach to defectiveness which involves stems and affixes; and (ii) deriving the inflection stratally. The proposal is summarized in (23).

(23) **Proposal on the functions of tone**

a. Nuer has a bidirectional defectiveness:
   (i) Inflection exponents consist of toneless affixes or floating H(L) or L tonal trees which operate on different strata
   (ii) Stems show a three-way underlying tonal contrast:
   stable, hybrid, and unstable
b. The targets of floating tones (inflectional tone and H tone epenthesis) depend on the underlying representation of stems:
   (i) Stable stems have a full lexical tonal structure → Floating tones cannot overwrite the stem tone
   (ii) Hybrid stems have a floating lexical tonal tree → Floating tones can overwrite the stem tone at an early stratum before the lexical tone has linked to the stem
   (iii) Unstable stems have a floating lexical tone but lack a root node → Tonal trees can freely link to their stem at early and late strata

1.6 Outline of the dissertation

The remainder of this dissertation is structured as follows. There are three parts of the dissertation which build upon each other. In the first part, I present evidence for the realization and representation of lexical tone: In chapter 2, I discuss the phonemic status of lexical tone. An important topic here is whether tone interacts with other components in the phonology such as voice contrast. In chapter 3, I present evidence of the phonetic correlates in the production on tone. This is followed by an experimental study on the perceptual contrastiveness between HL and L tones in chapter 4. The next part of the dissertation regards tonotactics, where I discuss evidence of H tone epenthesis which is due to the Obligatory Contour Principle on L tones. Data and generalizations of this restriction are given in chapter 5. The phonetic nature of H tone epenthesis in a noun – verb sequence is presented in chapter 6. The part on L tone distribution concerns mainly the phonological nature of this phenomenon which is necessary to understand before exploring tonal interactions.

This final part of this dissertation concerns the function of tone in nominal inflection, which ties together all components of this dissertation. Chapter 7 provides data and descriptive generalizations of inflectional tone and its interactions with underlying tone and H tone epenthesis. A theoretical background is given in chapter 8 on Stratal Optimality Theory, which I employ in chapter 9 to provide a formal account of how nominal inflection is derived in Nuer in relation to tone and suffixation. This concerns a Stratal OT proposal of the serial interaction between lexical tone, H tone epenthesis, and inflectional tone. Chapter 10 concludes the findings of this dissertation and discusses some of the loose ends from this study.

Part I

Lexical Tone

Chapter 2

Tonemes in Nuer

This chapter examines lexical tonal contrasts in Nuer nouns. I claim that there are three underlying tones: H, L, and HL. In addition, some nouns have a mid-level tone which alternates with a rising tone in sentence-initial position. Tones appear unrestricted on modal vowels. Breathy vowels, on the other hand, are restricted to level tones.

This study shows no correlation between tone and vowel length, i.e., H, L, and HL tones are all found on short, mid, and long vowels. Tonal minimal pairs with syllables of different vowel length are shown in section 2.1. Section 2.2 gives an overview of the surface tones which are found in different sentence positions, including nouns with a mid tone. To foreshadow chapters 5 and 7, the phonetic realization of sentence-medial mid tones is identical to epenthesized H-toned nouns derived from L tones.

Section 2.3 discusses the correlation between phonation and tone. While modal-voiced nouns appear with all tones, breathy vowels are not found with HL tones, only with H and L tones. For this reason, the correlation between phonation and tone seems to be restricted to breathy vowels. The fact that modal vowels can have all tones might be unique to the Ethiopian variant of Nuer. Section 2.4 summarizes the findings on lexical tone.

2.1 Contrasting tones

Minimal pairs are a good indicator of contrastive tones in a language. The examples in (24)–(26) show minimal tonal pairs of HL vs. L tones, and H vs. L tones.

Minimal tonal pairs

(24) a. lâ̪t HL
'cotton'
b. là̪t L
'shaking'

(25) a. wâːr HL
'sheep/goat dung'
b. wàːr L
'kind of grass'

(26) a. bɛ̤́r H
'Anuaks'
b. bɛ̤̀r L
'length'

There are many near minimal pairs of tone where also vowel length, voice quality or vowel quality changes in addition to tone. In (27) and (28) below, two examples are given of near minimal pairs which change in vowel length and phonation together with the tonal specification.

(27) a. cùˑk HL
'water pot'
b. cúk H
'to shorten/tighten'

(28) a. bâr HL
'lakes'
b. bà̤r L
'to run'

Several minimal pairs or near minimal pairs differ in grammatical meaning. For example, the difference between the nominative and oblique case of the noun *kôt̪* is tone. In the nominative case it has a HL tone, whereas in the oblique case it has a L tone (29). Most of these alternations happen with additional segmental changes. An example of this is the nominative case of the noun 'boy' which changes the tone, phonation, vowel quality, and duration in the oblique case (30). The fact that other stem-internal changes accompany tone alternation is a frequent pattern in Western Nilotic languages and has been reported for, e.g., Dinka, Shilluk, and Thok Reel (Andersen 1995; Remijsen et al. 2016; Reid 2010).

(29) a. kôt̪ HL
god
b. kòt̪ L
god\OBL

(30) a. d̪ɔ̤́ːl H
boy
b. d̪ʊ̀l L
boy\OBL

I claim that the syllable is the Tone Bearing Unit (TBU) in Nuer. All tones are found on syllables with the three contrastive vowel lengths in Nuer. As can be seen in (31)–(33), H, L, and HL tones are realized on short, mid and long vowels. If the mora were the TBU, it would be expected that short syllables would restrict the surface tonal contrasts compared to long syllables, which is not what is found in this study.

(31) HL
  a. jâŋ
   'cow'
  b. lɔ̂ˑc
   'heart'
  c. tɛ̂ːr
   'September'

(32) H
  a. ké̤r
   'calabash plants'
  b. hɔ́ˑk
   'cows'
  c. d̪ó̤ːl
   'boy'

(33) L
  a. tɔ̤̀t
   'summer'
  b. ɲàˑl
   'girl'
  c. kè̤ːr
   'line'

The data in (31)–(33) contradict the generalization made by Yigezu (1995), namely that complex tones only appear on long vowels. Additional evidence for that the syllable is the TBU comes from nouns changing vowel length in inflection. The forms below in (34)–(35) retain a HL tone regardless of vowel length alternations.[1]

(34) 'gourd '
  a. tɔ̂ˑk SG
  b. tôːk PL

(35) 'lake'
  a. bâˑr SG
  b. bâr PL

If the mora is considered the TBU in Nuer, it falsely predicts that vowel shortening leads to a level tone. The claim made here, namely that the syllable is the TBU, correctly predicts that HL tones do not (have to) become level tones with vowel shortening.

2.2 Surface tones in context

In addition to H, L, and HL tones, a few nouns and verb forms were found with a mid tone in this study.[2] Words with mid tones are sometimes realized as a rising tone in sentence-initial position. That is, some speakers realize fairly consistently the low-high allotone sentence-initially, while other speakers tend to realize it as mid even in sentence-initial positions.

The surface contrast of all four tones can be observed in sentence-final positions after the imperative form of the verb. Below, L and HL tones can be seen in (36)–(37), and H and mid tones can be observed in (38)–(39).

[1] See chapter 7 for a discussion of whether the alternation of nouns such as 'lake' in (35) involve vowel shortening from singular to plural, or whether the plural is the unmarked form.

[2] In total, eight nouns have a mid tone in the data collection of 80 nouns, and one noun has a mid tone in the data collection for the production experiment.

Note that the tone of this verb form itself is peculiar. It has a high-level tone (*nɛ́n*) before a L or HL tone, and a mid-level tone (*nɛ̄n*) before a H or another mid tone. I transcribe this verbal tone as it is phonetically realized without committing to its underlying tone.[3]

(36) L-toned nouns

a. nɛ́ˑn wàːr
see.IMP.SG grass
'Look at the grass!'

b. nɛ́ˑn nè̤ˑn
see.IMP.SG mirror
Look at the mirror!'

(37) HL-toned nouns

a. nɛ́ˑn wâːr
see.IMP.SG sheep.dung
'Look at the sheep dung!'

b. nɛ́ˑn rɔ̂ːm
see.IMP.SG sheep\PL
Look at the 'sheep!'

(38) H-toned nouns

a. nɛ̄ˑn cí̤e̤k
see.IMP.SG woman
'Look at the woman!'

b. nɛ̄ˑn wá̤ˑn
see.IMP.SG thieves
Look at the thieves!'

(39) M-toned noun

nɛ̄ˑn lā̤ˑm
see.IMP.SG kind.of.fish
'Look at the fish!'

Another context where all four tones are realized is when a H-toned auxiliary precedes the noun. In (40), H-toned nouns follow the auxiliary and precede a L-toned verb. In (41), L-toned nouns follow the H-toned auxiliary.[4]

(40) H tones

a. hē̤n c-é̤ tét nɛ̀ˑn
1SG PFV-1SG hand see
'I have seen the hand.'

b. hē̤n c-é̤ wɔ̤́ˑk nɛ̀ˑn
1.SG PFV-1SG shoulder see
'I have seen the shoulder.'

(41) L tones

a. hē̤n c-é̤ nè̤ˑn nɛ̂ˑn
1SG PFV-1SG mirror see
'I have seen the mirror.'

b. hē̤n c-é̤ cɔ̤̀a̤ː nɛ̂ˑn
1SG PFV-1SG bone see
'I have seen the bone.'

HL-toned nouns can be observed in the same context after the H-toned auxiliary in (42). In this context, some nouns surface with a mid tone (43). Phonetically, they are realized at the same level as the personal pronoun *hē̤n*. This pronoun is realized as a rising tone by some speakers because of its sentence-initial position: *hě̤n*.

[3]See chapter 3 and 4 for phonetic details on f_0 of *nɛn*.

[4]Note that the verbal stem *nɛˑn* gets a HL tone because of its underlying structure which permits H tone epenthesis – see chapter 5. This HL tone also appears after mid tones – see chapter 10.

(42) HL tones

a. hē̤n c-é̤ dɛ̂ˑl nɛ̀ˑn
1SG PFV-1SG sheep/goat see
'I have seen the sheep/goat.'

b. hē̤n c-é̤ kêːr nɛ̀ˑn
1SG PFV-1SG calabash.plant see
'I have seen the calabash plant.'

(43) Mid tones

a. hē̤n c-é̤ cɔ̤̄ˑw nɛ̂ˑn
1SG PFV-1SG bone\PL see
'I have seen the bones.'

b. hē̤n c-é̤ twɔ̤̄ˑt nɛ̂ˑn
1SG PFV-1SG wild.goose see
'I have seen the wild goose.'

An example of a rising tone realization of a M-toned word is given in (44).

(44) Low-high realization

twɔ̤̌ˑt gwà-ɛ̀ː
wild.goose good-3SG
'The wild goose is good.'

Nouns with mid tones such as *lā̤ˑm* (39), *cɔ̤̄ˑw*, and *twɔ̤̄ˑt* (43) are different from H, HL and L tones because (i) they are not as frequent, and (ii) they have the low-high allotone. The phonemic status of this tone is not entirely clear. They were found fairly late in this study, and I failed to find any minimal pairs of mid tones contrasting with H, L, or HL tones. It is possible that their underlying specification involves two tones: a linked tone and a floating tone. A few hypotheses will be discussed in chapter 10. However, because their infrequent occurrence and the lack of minimal pairs, I choose to remain agnostic on their underlying tone and transcribe them with a surface mid tone.

2.3 Tone and voice quality

As mentioned in chapter 1, Nuer has a voice distinction in vowels: modal and breathy voice. The interaction between tone and phonation in Nuer is complex. The main reason for this complexity is that these two features correlate in the inflectional morphology. This study indicates that tonal contrasts are restricted to modal vowels. That is, while modal vowels can bear a H, L, M, and HL tone, breathy vowels only surface with a H, L, and mid tone. In addition, the data set shows a tendency for HL tones to appear on modal-voiced vowels, and H tones to appear on breathy-voiced vowels. At a first sight, this might seem like an allophonic alternation resulting only from phonation, and Monich (Forthcoming) shows that in other dialects of Nuer, the correlation between HL and H tones relies solely on phonation. For this study on the Ethiopian Jikany variant, a few observations below indicate that this tone alternation does not only rely on phonation.

In this study, no breathy vowels were found with HL tones, and they only appear either H tones as in (45), L tones as in (46), or mid tones as was shown in (43) above.

(45) H tones

a. kɛ̤́ːt ‘eagle’
b. kó̤ːr ‘stream’
c. dé̤t ‘sheep/goat’
d. tɛ̤́ɐ̤ː ‘secrets’
e. mó̤ˑk ‘buffalo’

(46) L tones

a. dò̤ːr ‘hermaphrodite’
b. wɐ̤̀t̪ ‘warriors’
c. kè̤ːr ‘line’
d. tɔ̤̀t ‘summer’
e. cɔ̤̀a̤ː ‘bone’

An interesting inter-speaker variation is worth noting for the inflection of the noun ‘gourd’ (a type of vegetable). The singular form has a modal vowel with a HL tone for both speakers. For speaker A (47), the plural forms also have a HL-toned modal vowel. Speaker B, however, pronounces the plural form consistently with a breathy vowel and a mid tone (48). The fact that the breathy form in (48b) is realized with a level tone gives additional evidence for the restriction of breathy vowels with contour tones.

(47) Speaker A

a. tɔ̂ˑk ‘gourd’
b. tôːk ‘gourds’

(48) Speaker B

a. tɔ̂ˑk ‘gourd’
b. tō̤ːk ‘gourds’

Modal vowels, on the other hand, appear with either a H, L, M, and HL tones. Some examples are shown in (49)–(52) below.[5]

(49) H tones

a. hɔ́ˑk ‘cows’
b. múˑl (name)
c. wíː ‘villages’

(50) L tones

a. lòɲ ‘lion’
b. làˑŋ ‘mosquito net
c. ɟɔ̀k ‘back’

(51) Mid tone

nʊ̄p ‘message’

(52) HL tones

a. jâŋ ‘cow’
b. mɛ̂ˑŋ ‘curve’
c. dɛ̂ˑl ‘sheep’ (SG)

There are singular – plural alternations with a H tone in both forms. For example, both the singular and plural forms of ‘soil’ have a short modal vowel with a H tone (53a)– (53b). The phonation type contrasts with the oblique singular form which has a breathy vowel and a L tone (53c). This phonation difference is perceivable and acoustically measurable – see section 1.1 for more on acoustic correlates in phonation.

[5] The name *múˑl* is pronounced with a L tone *mùˑl* by some speakers.

(53) ‘soil’

a. mún SG
b. mɔ́n PL
c. mṳ̀ɔ̤ːn SG.OBL

Another example of a H-toned noun with a modal voice is *tét* ‘hand’. The singular and plural forms are syncretic in that they are segmentally and suprasegmentally identical (modal short vowel with a H tone). These nouns have a voice distinction in other dialects of Nuer, while this study indicates that the voice distinction for this noun is lost. The speakers realize it with a modal vowel in both the singular and plural forms. Acoustic measurements show no difference in vowel quality or breathiness among the speakers. Thus, the context determines which form is singular or plural. For example, in (54a) the speakers pronounce the noun with the singular form of the predicate *gwàɛː*, and the singular possessive marker in (54b). In comparison, the same form is pronounced with the plural form of the predicate *gɔ̀w-kɛ́ː* in (55a), and a plural possessive marker (55b).[6]

(54) a. tét gwà-ɛ̀ː
hand good-3SG
‘The hand is good.’

b. téd-dɛ̀
hand-POSS.3SG
‘her hand’

(55) a. tét gɔ̀ˑw-kɛ́
hand\PL good-3PL
‘The hands are good.’

b. tét-kɛ̀
hand-POSS:PL.3SG
‘her hands’

Monich (Forthcoming) claims that HL and H tones are allophonic on vowels which alternate in breathiness. Breathy vowels never appear with HL tones, only with H tones, while modal vowels only appear with falling tones. That observation differs from this study where modal vowels can have both H and HL tones. A comparison of the data demonstrates a dialectal difference. Monich and Baerman (2018) present the singular and plural form of ‘hand’ shown in (56). The two forms contrast in tone and voice; the singular form has modal voice with a HL tone, while the plural forms has breathy voice and a H tone.

(56) Data from Monich and Baerman (2018)

a. têr̥ ‘hand’
b. té̤r̥ ‘hands’

When comparing the forms in (54)–(55) with the data in (56) above, Nuer appears to have dialectal differences concerning phonation and tone. It is possible that other forms, such as the plural form of ‘soil’ *mɔ́n* in (53), are breathy in other Nuer dialects. This indicates two

[6] Note that the coda of *tét* gets voiced when the possessive marker attaches.

things: First, modal-voiced vowels appear unrestricted with all tones in the dialect of this study, therefore, it seems unlikely that the realization of HL and H tones depend on phonation alone. Second, since other dialects of Nuer have a two-way restriction on phonation and surface tones, it is possible that Ethiopian Jikany previously had this restriction and is now losing breathy voice. Under that hypothesis, this variant of Nuer has retained level tones on modal vowels which once were breathy.

The question remains why breathy vowels fail to surface with HL tones. From a phonetic perspective, it has been shown that breathiness in many languages has a lowering effect on f_0. A few hypotheses might be relevant for Nuer. One is that breathiness in vowels contribute to lower the H portion of the fall which flattens out the contour of HL tones – see also section 3.1.3 and 3.4.1 in the next chapter for more discussion on breathiness and f_0. Another hypothesis is that a HL tone on breathy vowels is perceived as level because f_0 is realized only in the first part of the segment. This phenomenon has been found in the acoustic study of Amuzgo by Herrera Zendejas (2000). According to this study, vowels referred to as breathy or 'ballistic' are realized with modal voice initially and with a breathy voice in the final part. The study reports that f_0 is only detected and perceived in the initial, modal, part of the vowel. In the breathy part, f_0 is not realized due to the amount of aspiration and friction in the vowel. The hypothesis is that phonation stops for a period of the vowel because the larynx is too open during the passing airflow.

For some languages, the opposite has also been observed, namely that the breathiness contributes to a slight pitch rise at the end of the vowel due to an increase in airflow. Such increased airflow might have a raising effect on f_0. This has been reported in Comaltepec Chinantec (Silverman, 1994) where ballistic syllables undergo a slight f_0 rise towards the end of the syllable. Such phonation effects on f_0 might 'flatten' out the fall of HL tones in breathy vowels. This would make HL tones indistinguishable from H tones on breathy vowels. An additional possibility is that the HL tones in breathy vowels get simplified to mid tones. This was the case for speaker B in (48). However, this hypothesis would falsely predict that f_0 of modal H-toned vowels is different from breathy H-toned vowels. In this study, the f_0 of breathy H nouns is not noticeably lower than H tones of modal vowels – see section 3.4.1.

There might be a non-phonetic reason for why breathy vowels tend to have H tones, namely because it is a grammatical phenomenon. I argue that this is the case for Nuer. In chapter 7, I will show that plural number is marked by a H tone. Plural stems are often breathy and as a consequence also have a H tone. This might explain why there is a bias for breathy nouns to have a H tone. In other words, the observed correlation between phonation and tone might be due to the grammatical nature of H tones.

2.4 Summary

To conclude, there is evidence for a H, HL, L lexical tone contrast in Nuer where the TBU is the syllable. On the surface, there are also mid tones which have an allophonic low-high variant. These rising tones only appear as a phonetic variety of mid tones at the beginning of utterances. While minimal pairs indicate an underlying contrast between H, L, and HL tones, there are no minimal pairs found for mid tones. Mid tones are also very infrequent compared to H, L, and HL tones.

The rest of the data presented in this chapter indicated that modal vowels appear unrestricted with all tones. Diachronically, this might be due to a loss of breathiness in Nuer vowels. Breathy vowels have a tone restriction and only appear with H, L, or mid tones. The impossibility of HL tones to occur on breathy vowels can be due to different phonetic factors. I do not rule a phonetic impact but consider a grammatical account of this restriction more likely because H tone marks plural, and plural stems tend to have breathy vowels – see chapter 7. Synchronically, I claim that H, L, and HL tones are underlying. Regardless of not having found minimal pairs of H – HL tones, there are near minimal pairs of these two tones, and modal vowels do surface with both H and HL tones. In other words, HL tones appear on short, mid and long vowels with different vowel quality and phonation. As Reid (p.c) has pointed out for Lɔu Nuer, it would not be expected that both HL and H tones occur on modal vowels if they were not phonemic.

Chapter 3

Acoustic correlates of tones

The previous chapter established that Nuer has underlying H, L, and HL tones. Assuming these tone are contrastive, it is expected that each tone can be distinguished phonetically without overlapping with each other. The most relevant correlate to measure tone is fundamental frequency (f_0). The reason for this is that tone is produced through vibration in the vocal cords, and f_0 is a measurement of the rate of vocal fold vibration. That is, f_0 stands for the number of *periods* (opening and closing) of the vocal cord vibration per second and is measured in Herz (Hz). Changes in f_0 result from altering the tension of the vocal cords (see Ohala 1978 for details on the different mechanisms of this). F_0 is the acoustic parameter of perceived pitch and, therefore, in languages with contrastive tone, it is expected that f_0 is the main correlate which distinguishes one tone from another. For example, a H tone is expected to have higher f_0 compared to a L tone, and a M tone is expected to have f_0 values which lie between a H and a L tone. Measuring f_0 is, therefore, the main method for examining tone. If Nuer has contrastive tone, then minimal pairs such as *làt̪* 'shaking' and *lât̪* 'cotton', or segmentally similar words like the singular – plural distinction in 'eye': *wà*ŋ (singular) *wé̤*ˑŋ (plural) are expected to differ significantly in f_0 across speakers.

After a brief background on tonal correlates in Nuer and possible effects on f_0 in section 3.1, I report the methods of this study in section 3.2. This involves measuring the f_0 midpoint and the slope of the nucleus of monosyllabic nouns in four different sentence types. The results of these measurements are presented in section 3.3 where I report the phonetic correlates for H, L, and HL tones in Nuer. In addition, it is shown that the tones are subject to final lowering. These results provide a detailed picture of the Nuer tone system. Section 3.4 discusses the production data in relation to phonation and mid tones, and section 3.5 concludes the results.

3.1 Background

3.1.1 Tonal correlates and measure points of f_0

There are different ways to measure f_0 depending on the type of tonal targets. Contrastive tone levels differ in f_0 height when pronounced in the same environment. For example, the f_0 value of a H level tone reaches a target at the upper level of a speaker's tonal space. A L level tone reaches a point which is lower than, e.g,. a H tone. At or near the end of an utterance, this can be at the bottom of a speaker's tonal space or near it. Regarding the differences between contour and level tones, the main contrast is found horizontally on the time axis. It has been shown that tones differ regarding the alignment of the fall (see Bruce 1977; Remijsen 2013c; Remijsen and Ayoker 2014; among many others). These studies have shown that the main difference between a falling HL tone and a L tone which both follow a H target lies in the timing of the fall. For example, while a HL tone on a monosyllabic word falls from a high target towards a low target within the nucleus, a L tone starts to fall earlier and has already reached a low point in the nucleus.

The graph in Figure 3.1 below illustrates the essential differences between H, L, and HL tones in Nuer of the words *ɲá̤ˑr* 'gums', *mâˑl* 'peace', and *ŋà̤ˑm* 'cooked maize' pronounced by a female Nuer speaker. All three tones start approximately at the level of the preceding phonetic high target of *nɛˑn* 'see' (IMP.SG). The L tone (dotted line) and the HL tones (dashed line) start a little lower than the H tone (solid line). The L tone begins to fall at the beginning of the onset of the target word. Already by the nucleus, it has reached a low point which is close to the bottom of the speaker's tonal space. The HL tone has a similar movement in that it also falls. The main difference is that the fall starts later, i.e. at the beginning of the nucleus of the target word. The fall of the HL tone is steepest in the nucleus. In comparison, the L tone has a shallow fall here due to declination. The H tone roughly retains the high level of the preceding syllable. Phonetically, there is a tiny rise towards the vowel onset. It reaches the maximum of the speaker's tonal space at the beginning of the nucleus. From this point, there is a shallow decline towards the utterance end. It is visible from this graph that the main contrast between the H tone and the L tone is f_0 height. The H and the L tone show the greatest contrast of f_0 height at the midpoint of the nucleus (marked with circles). The HL tone is situated between the H and the L tone. In other words, all three tones contrast in f_0 at the midpoint of the vowel nucleus making this a meaningful point to measure.

When the focus is on the difference between a L tone and a HL tone, the biggest f_0 height contrast is found at the vowel onset. In this experiment, the chosen measure point for this is at the 1/10th into the nucleus. This time point is still not at the exact boundary of the consonant-vowel, and microprosodic effects are, therefore, minimized. Figure 3.1 below shows this measure point with a square.

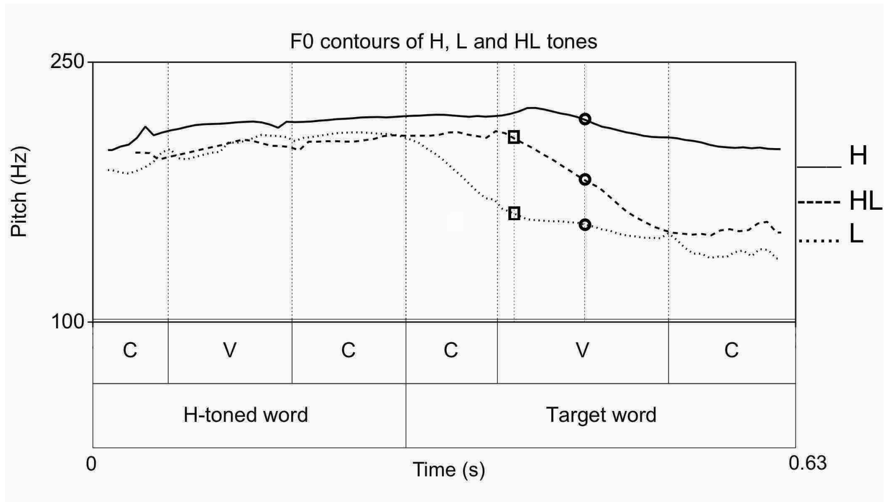


Figure 3.1: Tokens pronounced by a female Nuer speaker showing f_0 contours of three target words with a H, L, and HL tone. The words are pronounced in a sentence-final position following an initial high target. The circles show the midpoint measure points (1/2 into the nucleus), and the squares show the vowel onset measure points (1/10 into the nucleus).

3.1.2 Downtrend phenomena

There are a variety of factors which can condition f_0. The most relevant phonetic factors for this study concern the position in the utterance and the surrounding tones. First, the position in the utterance can affect f_0 in different ways. In sentence-final words, f_0 will be lower compared to when it is pronounced medially or initially. One factor which can cause this effect is called *declination*. Declination has been defined as a gradual fall-off or downslope throughout the utterance (Cohen and ’t Hart 1967; Vaissère 1971; Vaissière 1983; Ladd 1984, among others). Studies show that a sentence-initial H tone has a higher f_0 than a H tone which is pronounced towards the end of a sentence. This is often a phonetic effect due to declination which tends to occur within an utterance. Effects of declination are not prominent in the results of this experiment because of the short length of the tested utterances. However, it appears that when comparing two sentences, the tones of the sentence which is one syllable longer are slightly lower than the tones in the shorter sentence.

Another downtrend which affects f_0 is called *downstep*. I will restrict this topic here to *automatic downstep* which lowers H or mid tones which follow a L tone (Pulleyblank, 1986; Stewart, 1983, 1993). The degree to which automatic downstep affects f_0 is different from declination because it is a local assimilation between a L and H tone. Declination, on the other hand, applies globally to the entire utterance. For example in Hausa, Lindau (1986) compares the effects of declination alone with the effects of declination combined with automatic downstep. In the former case, the effect of declination can be isolated because the tested utterances contain only H tones. In the latter case, the tested utterances contain both H and L tones causing automatic downstep. Lindau found that the utterances with automatic downstep decline more steeply than the utterances with only H tones. In Nuer, it appears that the L component of HL tones lowers the following H tones.

Another downtrend phenomenon relevant for this study is called 'final lowering'. This is a type of lowering which affects a specific target at the very end of an utterance (see Liberman and Pierrehumbert, 1984). This lowering mechanism differs from declination in that it affects a domain, e.g., a syllable, to a more extreme degree than the lowering caused by declination. For languages with final lowering, one often postulates a L boundary tone (L%) which appears at the end of the sentence. If final lowering is phonetic, the L% tone is not expected to interact with other tones in the language. It can vary greatly from language to language how strongly f_0 is affected by final lowering. In Nuer, the results of this study indicate that final lowering is phonetic and applies to the nucleus and coda final in utterances.

3.1.3 Segmental effects on f_0

At the segmental level, factors such as vowel height, consonant context, and phonation can affect f_0. This is known as microprosody. For example, high vowels tend to have an intrinsic f_0 which gives them higher pitch compared to low vowels (Lehiste 1970; Whalen and Levitt 1995, and further references therein). Voiceless plosives can raise f_0 in the vowel onset, and voiced plosives can lower f_0 (Ewan and Krones 1974; Ohde 1984; Stevens 1998, among many others). It has been shown that breathy voiced consonants lower f_0 even more than voiced consonants (see Hombert et al. 1979 and further references therein). Breathy voice is characterized by a turbulent airflow of a large volume which passes through the glottis. To use the expression of Catford (1977), the vocal cords are 'flapping in the breeze' during this airflow, and one perceives a voice mixed with breath. In vowels, it has been observed that breathy voice often induces lowering on f_0. As Gordon and Ladefoged (2001: 387) formulate, "[b]oth the breathy voiced and the creaky voiced vowel are characterized by decreased intensity in the waveform, as well as lowered fundamental frequency relative to the modal voiced vowel. In addition, the breathy voiced vowel is marked by substantial turbulent energy which makes it difficult to discern individual pitch pulses".

In this experiment, the material tested contains breathy vowels. These are mostly H-toned nouns. HL-toned nouns are modal, while L-toned nouns are mixed. The bias between phonation of HL and H tones was difficult to avoid when selecting the target words because, in Nuer, plural nouns often have a breathy vowel in the stem and a H tone – see section 7.3 for more on this. Concerning phonation as a possible factor for f_0, breathy H-toned vowels are expected to be lower than modal ones. However, the results here show that they are not affected to the degree that they overlap with the other tones. Section 3.4.1 discusses this further by examining f_0 means of nouns separately.

3.2 Methods

3.2.1 Material

In this experiment, I test the phonetic correlates distinguishing the H, L, and HL tones. The data set of this experiment consists of 30 lexical items which are listed in Table 3.1 below. All items are monosyllabic nouns with either a H tone (8 items), a L tone (10 items), or a HL tone (12 items). The tone of these nouns was determined based on qualitative work before the experiment. All the target words have a sonorant onset, and most of them have a sonorant coda. The majority of the nouns have an open vowel, while a few have either a half-open or half-closed vowel. The vowels of the nouns are either short, half-long, or long. Breathiness was not possible to control for and most of the H tone nouns have a breathy vowel. Only one H-toned noun has a modal vowel, *mɔ́n* 'soils' – see sections 3.1.3 (above) and 3.4.1 (below) for more on this.

Noun	Gloss	Noun	Gloss	Noun	Gloss
HL tone		H tone		L tone	
jâŋ	'cow'	mɔ́n	'soils'	lòɲ	'lion'
ɲân	'kind of grasshopper'	wé̤ˑn	'thief'	làt̪	'shaking'
mân	'mother'	ɲé̤ˑr	'gum'	ŋà̤ˑm	'cooked maize'
mâŋ	'wave'	ɲá̤ˑr	'gums'	nè̤ˑn	'mirror'
lâˑm	'curse'	ɲé̤ˑŋ	'crocodiles'	lò̤ˑl	'deep water part of the river'
lât̪	'cotton'	wá̤ˑn	'thieves'	ɲàˑl	'girl'
mâˑl	'peace'	wé̤ˑŋ	'eyes'	làˑŋ	'mosquito net'
mɛ̂ˑŋ	'curve'	né̤ːr	'uncle'	wàŋ	'eye'
ɲâˑŋ	'crocodile'			wàːr	'grass'
wâːr	'sheep dung'			màːr	'relationship'
mâːr	'my mother'				
lêːr	'prostitutes'				

Table 3.1: Lexical items used in the elicitations.

Each noun in Table 3.1 was embedded in four different carrier sentences with varying forms of the verb *nɛˑn* 'see' (57). The segmental targets which were measured for f_0 were the preceding syllable (underlined) and the nouns (in bold). In (57a), the target nouns were pronounced sentence-finally following a H tone (the imperative form, *nɛ́ˑn*). Note that the tone of this verb is lowered to a mid-level tone before a H tone. In (57b), the target nouns were pronounced sentence-finally following a mid tone (the person index *-kɔ̄n*). In (57c), the target nouns were pronounced sentence-medially following the same M-toned person index *-kɔ̄n*. Finally, in (57d), the target words were pronounced in sentence-medial position in the present negative form. Here, it follows the person index *-kɔ̂n* with a HL tone. These four sentence types will be referred to as *H_%*, *M_%*, *M_L*, and *HL_HL*, respectively. Note that (57c)–(57d) are minimal pairs in tone because the meaning of the auxiliary and the person index *ci-kɔn* are tonally dependent: L-M tone is the perfective aspect in *M_L*, while H-HL is the negative present in *HL_HL*. In both of the sentence-medial sentences, the target words precede the L-toned infinitive form of the verb *nɛ̤n*. It has a HL tone in (57d): *nɛ̤̂n*. Chapter 6 also tests this verb in relation to morphological tone and tone sandhi effects in addition to the targets marked in bold.

(57) *Carrier sentences*

a. n<u>ɛ̤́n</u> **wâːr**
see.IMP.SG sheep.dung
'Look at the sheep dung!' — *H_%*: Sentence-final following a H tone

b. nɛ̤́n-k<u>ɔ̄n</u> **wâːr**
see-3.PL sheep.dung
'We are seeing sheep dung.' — *M_%*: Sentence-final following a mid tone

c. cì-k<u>ɔ̄n</u> **wâːr** nɛ̤̀n
PVF-3.PL sheep.dung see
'We have seen sheep dung.' — *M_L*: Sentence-medial following a mid tone

d. cí-k<u>ɔ̂n</u> **wâːr** nɛ̤̂n
NEG-3.PL\NEG sheep.dung see\NEG
'We are not seeing sheep dung.' — *HL_HL*: Sentence-medial following a HL tone

3.2.2 Speakers and elicitation procedure

The recordings were made with six native speakers of Nuer (two females and four males). They were between 25 and 39 years old and were all speakers of the Gajaak variant of the Eastern Jikany dialect. The sessions took place at Addis Abeba University in Ethiopia. The participants were paid a fee for their contribution.

Each noun of Table 3.1 occurred in the four different carrier sentences in (57). The sentences were presented on slides written in Nuer orthography with the English translations. First, the citation form of the noun appeared on a slide. Then, the four different sentences were presented on a separate slide in a randomized order. The speakers were asked to pronounce the sentences in Nuer one time clearly. This procedure got repeated for all 30 nouns. The recordings lasted approximately 20 minutes for each speaker. There was one break after half of the slides had been presented.

The recordings were made using an H5 Zoom recorder with a Shure SM10A unidirectional, dynamic head-worn microphone. The sampling rate was 44.1 kHz with 16-bit quantization.

3.2.3 Data analyses

The data set consisted of 120 items and 720 tokens (30 nouns x 4 carrier sentences x 6 speakers). Because of background noises, hesitations, and because some nouns were not familiar to all the speakers, 27 tokens had to be excluded. This resulted in a total number of 693 tokens which were analyzed. For each token, the following targets were manually segmented and annotated in Praat (Boersma and Weenink, 2016): (i) the onset (o), nucleus (n) and coda (c) of each noun, and (ii) the nucleus (pn) and coda (pc) of the word preceding the target noun; -ɛ*n* in (57a) and -ɔ*n* in (57b)–(57d). These targets are marked in bold in (57) above. An example of a segmented token is given in Figure 3.2 below.

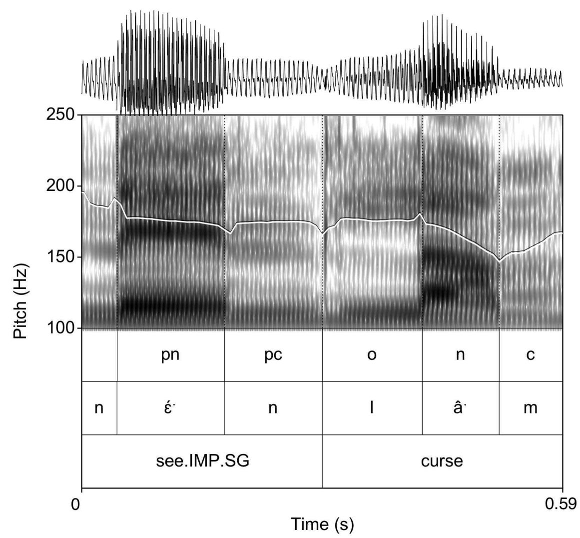


Figure 3.2: Waveform and spectrogram of a carrier sentence with the noun *lâ·m* 'curse' (translation 'Look at the curse.'). The first tier in this figure shows the annotated targets where f_0 was extracted.

F_0 was automatically extracted from PitchTier files together with the annotated TextGrids. First, pitch objects where automatically trimmed for spikes with the Praat script by Remijsen (2013b) using the algorithm in Xu (1999). The tokens were manually corrected for microprosodic effects on f_0. The pitch objects underwent two types of f_0 measurements. With the help of the Praat script by Remijsen (2013a), f_0 values were extracted at equidistant time points within intervals. First, the f_0 value at the midpoint of the nucleus was extracted with another Praat script. Second, the slope of the nucleus was measured by extracting f_0 at the 1/10th of the vowel and the 9/10th of the vowel. The initial point was subtracted from the final point of each target. The raw f_0 values (Hz) were converted to the semitone scale. This allows meaningful f_0 comparisons across the speakers. A semitone scale represents Hz values of f_0 in a logarithmic way. In a semitone scale, 12 semitones form an octave which is a doubling of f_0. Therefore, semitones (ST) are considered to be a closer representation of human perception of f_0. That is, it reflects 'subjects' intuitions of f_0 perception better than Hz and other scales (Nolan, 2003). Moreover, speakers' register differs, especially with respect to gender, but a semitone scale allows for a comparison across speakers which evens out such differences. The raw f_0 values were converted for each speaker into semitones in *R* (R Core Team, 2014) using the bottom of each speakers' f_0 range as a reference point. This conversion was done with the package *hqmisc* by Quené (2014) using the formula f2st(hz, base=92.3).

3.2.4 Statistical analyses

The null hypothesis for the experiment is the following: f_0 in Nuer is not affected by tone or sentence type. In the descriptive analyses, f_0 traces averaged across speakers were plotted on a normalized time axis. They revealed to what extent the three tones are phonetically contrastive in f_0 height and timing. If they do not contrast, their f_0 values will overlap.

In the inferential statistics, I tested the f_0 values at the midpoint and the slope in the nuclei of the nouns by first running a 2-way repeated measures ANOVA in *R* in the following way: The correlation between the dependent variable Midpoint ST as predicted by the two factors Tone and Sentence type was tested with the function *aov*, with Speaker as a random variable. A separate model was run on the correlation between Slope ST (dependent variable) and Tone + Sentence type (factors). The repeated measures ANOVA is used when each subject contributes to more data points. The interaction between the factor levels of Tone and Midpoint ST, and the levels of Sentence type and Midpoint ST were tested with pairwise T-tests. The same was done with Slope ST as the dependent variable. Adjustments of p-values were done with the Bonferroni correction in which the p-values are multiplied by the number of comparisons.

A Linear Discriminant Analysis (LDA) was run on Tone with the numerical variables f_0 Midpoint and Slope. LDA is used to model the differences between classes of data and is useful here for seeing to which degree the dependent variables can predict the classes of tones. The Herz values of these two variables were converted into Z-scores with a grouping by Speaker with the function *normLobanov*; package *phonR* (McCloy, 2016). LDA was also run with the same numerical variables on Sentence type as the categorical variable.

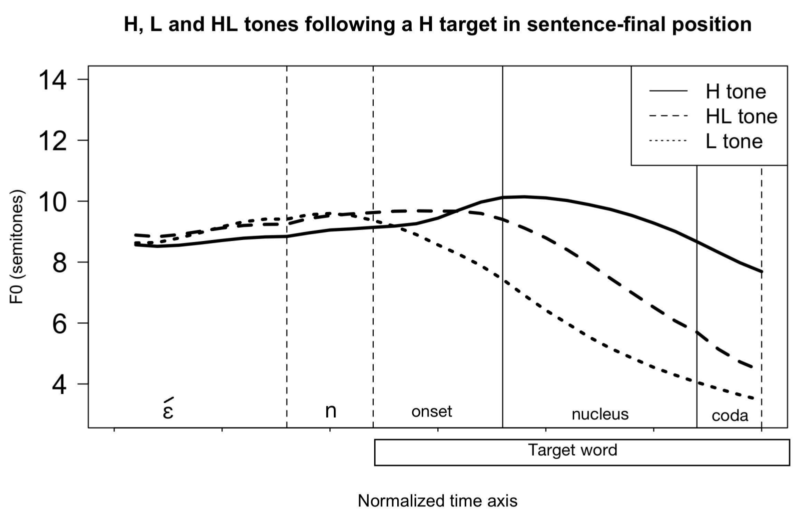
3.3 Results and discussion

3.3.1 Descriptive statistics

The graphs below in Figures 3.3–3.6 show the realization of lexical tones in each of the four carrier sentences. In these plots, f_0 traces are provided for monosyllabic nouns and the syllables (nucleus and coda) of the preceding targets. The values are averages over the realizations by six speakers. The solid lines are f_0 traces of H tone nouns, the dotted lines are f_0 traces of L tone nouns, and the dashed lines are f_0 traces of HL tone nouns.

In Figure 3.3, the target words are pronounced in sentence-final position following a H-toned syllable (*H_%*). The H-toned verb nucleus *nɛ́ˑn*, which precedes the target words in Figure 3.3, is approximately 9 ST high. It is visible that this verb has a slightly lower f_0 value when it precedes a H tone. Some speakers realize the tone of *nɛˑn* as a mid tone before a H tone in *H_%* – see section 3.4.2.

The H tone (solid line) starts to rise at the middle of the onset of the target words. It reaches the maximum height (around 10 ST) in the utterance at the beginning of the nucleus. About two thirds into the nucleus, it starts to fall gradually. This contrasts with the HL tone (dashed line) which does not rise in the onset. Instead, it remains at the same height as the preceding H tone of the verb *nɛ́ˑn*. At the boundary between the onset and the nucleus of the target word, the HL tone starts to fall in the nucleus. In the coda, it reaches a point near the bottom of the tonal space. For the L tone (dotted line), the fall starts earlier than the HL tone and is less steep. The f_0 trace starts to decline already at the very beginning of the onset of the target words. In the nucleus, the L tone has already dropped from 9 ST (at the beginning of the onset) down to 7 ST and is notably lower than the H and HL tones. The L tone continues to fall gradually until it reaches the lowest point in the utterance (approximately 3 ST). The course of the L tone fall is very similar to the HL tone. The main difference lies in the timing, i.e., whether the fall starts in the onset (L tone) or in the nucleus (HL tone).

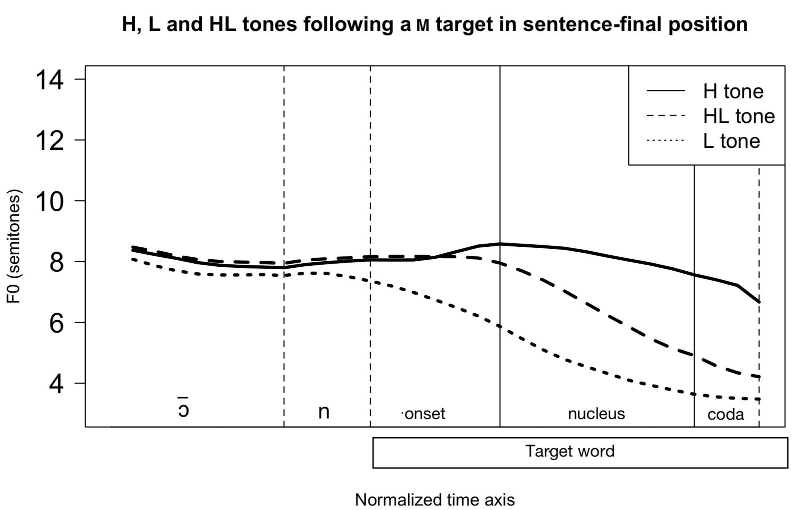


(58) *H_%*
n<u>ɛ́ˑn</u> **jâ**ŋ
see.IMP.SG cow
'Look at the cow!'

Figure 3.3: F_0 traces plotted from averaged values of all the elicited H, L, and HL nouns of six speakers. The target nouns are pronounced final in a carrier sentence following a H target. The x-axis shows the normalized time and the y-axis shows the semitone scale of f_0.

The f_0 traces of the target words in the carrier sentence *M_%* are shown below in Figure 3.4. They follow the M-toned person index -*kɔ̄n*, which is approximately 8 ST high. The f_0 -*kɔ̄n* lies between the H and the L tone of the following target nouns. In comparison to the H-toned imperative form of *nɛ́·n* in Figure 3.3, *-kɔ̄n* is about 1 semitone lower than *nɛ́·n*. The three tones show a similar contrast in the height and timing compared to *H_%* in Figure 3.3. As expected, the tones start from lower point because the preceding syllable is M. The main difference from *H_%* concerns the tonal space. Overall, the tonal space has a more narrow range when the H, L, and HL tones follow the M-toned syllable *-kɔ̄n* in *M_%* compared to when they follow the H-toned syllable in *H_%*. First, the tones start at the lower level than in *H_%*, but nevertheless, the endpoint of the fall is the same for both carrier sentences. Second, in *M_%*, the H tone is approximately 8.5 ST high and is barely higher than the preceding mid tone (7.8 ST). In comparison, the H tone in *H_%* reaches 10 ST (see Figure 3.3 above). In other words, the H tone in *M_%* does not reach the same height as in *H_%*. The sentence type *M_%* is one syllable longer than *H_%*. Although this is not much, it might be sufficient to cause declination on the tones.

The dotted line shows the L tones in *M_%*. As expected, they fall from the preceding mid tone in *-kɔ̄n* to the L tone target words. Also, the L tone continues to fall throughout the nucleus. This appears to be due to its final position in the utterance and indicates a phonetic final lowering.



(59) *M_%*
nɛ́n-kɔ̄n **jâ**ŋ
see-3.PL cow
'We are seeing the cow.'

Figure 3.4: F_0 traces plotted from averaged values of all the elicited H, L, and HL nouns of six speakers. The target nouns are pronounced final in a carrier sentence following a mid tone. The x-axis shows the normalized time and the y-axis shows the semitone scale of f_0.

The next two sentence types I will discuss have the target words in sentence-medial position. For the sentence *M_L* in Figure 3.5, each of the tones has a very similar f_0 trace compared to the graph of *H_%* in Figure 3.3 above. In the onset, the H tone (solid line) starts at about 9 ST and has a small phonetic rise to approximately 10 ST at the boundary between the onset and the nucleus. It retains this height throughout the nucleus rather than declining as happens in Figure 3.3 and 3.4 above. For the HL tone (dashed line), it has a similar shape as in Figure 3.3 as it starts to fall at the boundary between the onset and nucleus. The slope of the fall is less steep than for the utterance-final HL tones in Figure 3.3. The L tone (dotted line) starts to fall already at the beginning of the onset just as in *H_%* in Figure 3.3. The difference is that when it has reached a low target (in the middle of the nucleus), it does not continue to fall. This is a notable difference between the tones in *H_%* and *M_L*, namely that they do not reach a point as low at the end of the nucleus compared to when they are pronounced sentence-finally. This appears to be due to the sentence-medial position of the target words. That is, there is no final lowering here. Sentence-medially, the HL and the L tone overlap in the coda as they meet at slightly above 6 ST. The L tone reaches its minimum at the end of the nucleus and does not fall more than this. The H tone falls to a point slightly above 8 ST to reach the low target of the verb which follows.

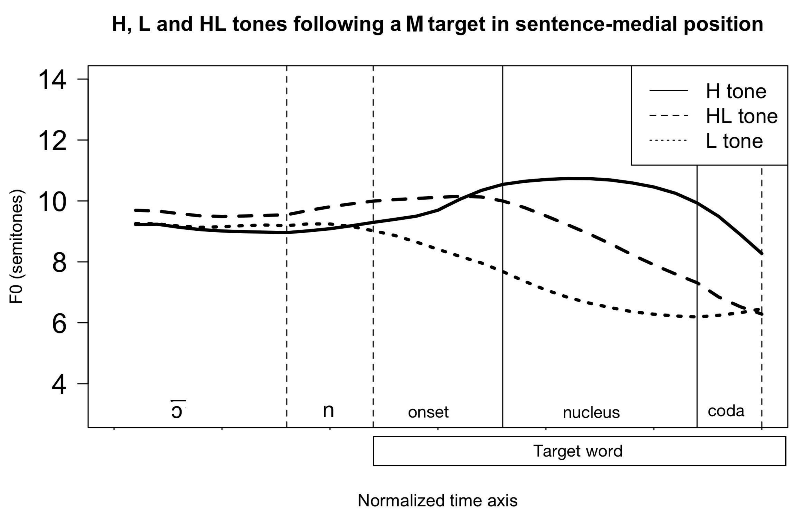


Figure 3.5: F_0 traces plotted from averaged values of all the elicited H, L, and HL nouns of six speakers. The target nouns are pronounced in a sentence-medial position following a mid tone. The x-axis shows the normalized time, and the y-axis shows the semitone scale of f_0.

(60) *M_L*
cì-k<u>ɔ̄n</u> **jâ**ŋ nɛ̀ˑn
PVF-3.PL cow see
'We have seen the cow.'

In Figure 3.6, the HL syllable preceding the target words of *HL_HL* starts at a high f_0 level at about 13 ST. It then goes down at the end of the nucleus where it reaches 9.6 ST. The starting point of 13 ST is higher than any other target in this study. It appears that the morphological nature of this sentence type, namely negation, is marked by an expansion in the pitch, perhaps an upstep conditioned by the H tone of the negation-marking auxiliary. In addition, the verbal stem *nɛˑn* is also marked by having a HL tone – see chapter 6 for measurements on this. Thus, it is tone which distinguishes the perfective (60) from the negative present since the auxiliary and verbal stem are segmentally identical.

Moreover, the sentence *HL_HL* in Figure 3.6 shows that the tonal space is compressed. That is, the H tone does not peak in the nucleus, but it is flatter compared to *M_L* and *H_%*. The slope of the HL tone is less steep compared to the latter two sentence types. These results indicate that the L target in HL which precedes the target word in *HL_HL* has a lowering effect on the following tones. Because of the upstep observed in *HL_HL*, the target words have higher f_0, but their tonal space is still narrow because of the preceding HL syllable. Concerning the L tones in *HL_HL*, they do not undergo final lowering as in *H_%* and *M_%*. Instead, the dotted line that goes from the coda *-n* in *cí-kɔ̂n* and throughout the target word is fairly flat. This indicates that *cí-kɔ̂n* reaches a L target of its HL tone in the coda. From here, following L-toned target words stays at approximately the same level.

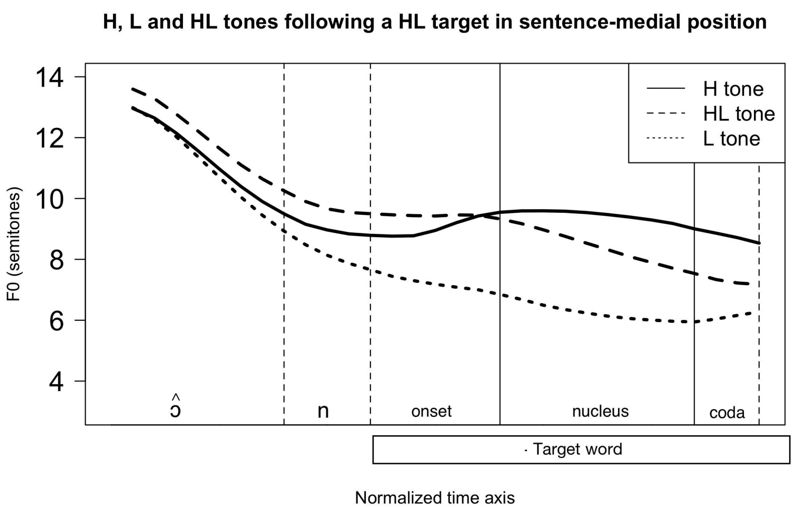


Figure 3.6: F_0 traces plotted from averaged values of all the elicited H, L, and HL nouns of six speakers. The target nouns are pronounced medially in a carrier sentence following a HL tone. The x-axis shows the normalized time, and the y-axis shows the semitone scale of f_0.

(61) *HL_HL*
cí-kɔ̂n **jâ**ŋ nɛ̂ˑn
NEG-3.PL\NEG cow see\NEG
'We are not seeing the cow.'

F_0 height

A scatter plot of the raw data points is given below in Figure 3.7. The plot has whiskers showing means and standard deviations. A prominent effect of Tone is visible in the plot. In general, the H tones have the highest semitone values, L tones have the lowest semitone values, and HL tones are in the middle. This mid-value of the HL tone is expected because f_0 drops from high to low across the nucleus. At the midpoint of the nucleus, f_0 has transitioned half-way down and is therefore at a mid-level between the H and the L tone.

The factor Sentence type also affects f_0. The sentence *M_%* has an overall lower semitone values compared to the other three sentence types. The averaged values, indicated by the black circles in the plot, show that H tones lie at 8 ST in *M_%*. In comparison, the mean f_0 is slightly above 10 ST in *M_L* and slightly above 9 ST in *H_%* and *HL_HL*. The same can be observed for the HL tone, which is slightly above 6 ST in *M_%*, slightly below 8 ST in *H_%*, and between 8–9 ST in *M_L* and *HL_HL*. The same trend can be seen for the L-toned nouns. They are lowest in *M_%* (slightly above 4 ST). Here f_0 increases a little for each sentence-type from right-to-left: In *H_%*, the mean midpoint is slightly above 5 ST, in *HL_HL* it is 6 ST, and in *M_L* it is slightly above 6 ST.

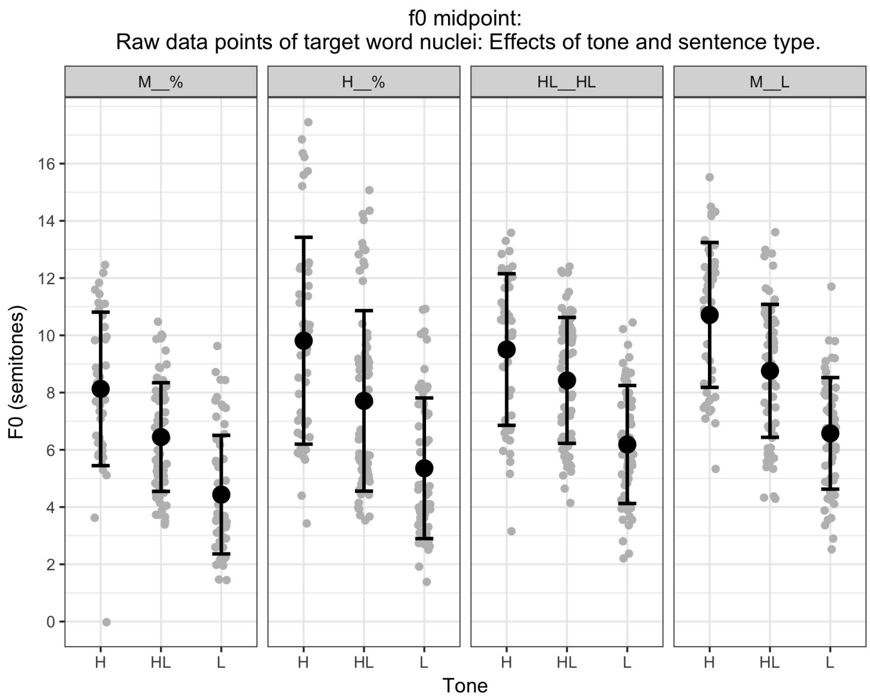


Figure 3.7: Raw data (gray dots) of nominal nuclei with whiskers showing standard deviations and averaged values (circles). The y-axis shows f_0 in semitones; the x-axis shows the tone of the target words. The effects of each of the four sentence types are plotted separately.

The exact means and the standard deviations are given in Table 3.2 below. These averaged values are helpful to indicate how the position of the target words are affected vs. how the preceding tone in the sentence type (H, L, or HL) affect f_0. As expected, the H tones are almost 1.5 ST higher in *H_%* compared to when they are in *M_%*. The HL tone is also nearly 1.5 ST higher in *H_%* compared to *M_%*. The L tones are less affected by preceding tones and are about 1 ST higher in *H_%* contexts. A similar pattern is observed for H tones in *M_L* and *HL_HL*. When comparing *HL_HL* with *M_L*, the H tones are about 1 ST lower in the former. The HL tone and the L tone, on the other hand, are nearly the same (0.3 ST lower) in *HL_HL*. This indicates that only the H tones are lowered in *HL_HL*.

Tone	M_%		H_%		HL_HL		M_L		All sentence types	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
H	8.12	2.68	9.81	3.61	9.50	2.64	10.71	2.53	9.57	3.02
HL	6.44	1.89	7.70	3.15	8.42	2.19	8.75	2.32	7.83	2.58
L	4.43	2.07	5.35	2.45	6.18	2.06	6.57	1.94	5.64	2.28

Table 3.2: Mean f_0 values (ST) of nuclei midpoints of H, L, and HL nouns in four different sentence types.

Finally, when comparing *M_L* with *M_%* in Table 3.2 above, the target words are in both cases preceded by a mid tone and the only difference is the position: final vs. medial. The f_0 averages indicate that f_0 in sentence-final position is lowered approximately 2 ST for all tones.

F_0 slope

The results for the slope in the nucleus of the nouns are shown below. Figure 3.8 shows all the data points for each Tone and Sentence type. The main pattern is that the HL tone has the most prominent slope, followed by the L tone, and then the H tone. There are quite large differences between the sentence types.

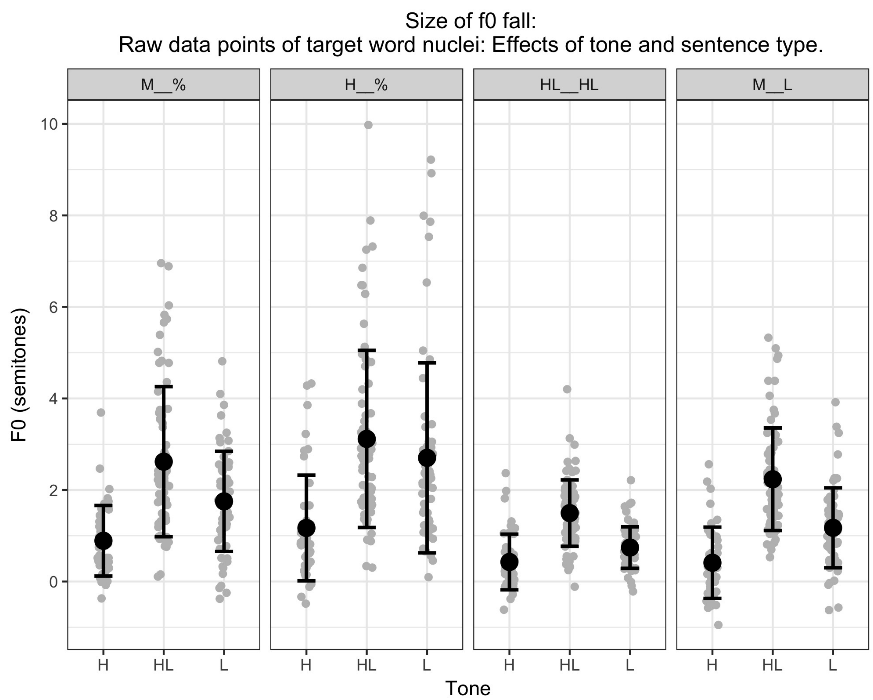


Figure 3.8: Raw data (gray dots) of f_0 slope of nominal nuclei with whiskers showing standard deviations and averaged values (circles). The y-axis shows f_0 in semitones. At 0, the tones are level. The x-axis shows the tone of the target words. The effects of each of the four sentence types are plotted separately.

Table 3.3 presents the means and standard deviations of the data points of Figure 3.8. In *M_%*, the averaged slope for HL is 2.6 ST. The slope of L is almost 1 ST lower (1.7 ST), while the slope of the H tone is less than 1 ST (0.8 ST). In *H_%*, the slopes are bigger for all tones. The HL tone has a slope of 3.1 ST, and the L tone is near this value (2.7 ST). The slope of the H tone is 1.1 ST, which is not much larger compared to its slope in *M_%* (0.8 ST). These values contrast with the two sentence-medial contexts where the slopes are smaller. In *HL_HL*, the HL tone is 1.4 ST, almost 1 semitone lower compared to in *M_%*. The same goes for the L tone which is 0.7 ST., i.e., exactly half the size of the slope of the HL tone in *HL_HL*. The H tone is less than half a semitone (0.4 ST). In *M_L*, the slope of the HL tone is 2.2 ST, and the L tone is again half the size of the HL tone (1.1 ST), while the H tone has the same slope as in *HL_HL* (0.4 ST).

Tone	M_%		H_%		HL_HL		M_L		All sentence types	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
H	0.89	0.77	1.16	1.15	0.42	0.60	0.41	0.77	0.71	0.90
HL	2.61	1.64	3.11	1.93	1.49	0.72	2.23	1.12	2.36	1.54
L	1.75	1.09	2.70	2.07	0.74	0.45	1.17	0.87	1.59	1.46

Table 3.3: Mean f_0 values (ST) of nuclei slope of H, L, and HL nouns in four different sentence types (f_0 value of vowel onset minus the value of vowel offset).

The values of Table 3.3 show that HL tones always have a falling contour which is bigger compared to the level tones. They also show that all tones undergo lowering in a sentence-final position. L tones fall more than H tones and have a slope very close to HL tones after a H tone in sentence-final position. In sentence-medial position, the differences are more clear between HL tones and the two level tones. The slopes of L tones are exactly half the size of HL tones, and H tones fall less than half a semitone. This supports the observation that tones in Nuer are subject to final lowering, which directly affects the slope of any tone.

3.3.2 Inferential statistics

F_0 height

The results of the two-way ANOVA test with repeated measures is given in Table 3.4. The factors Tone and Sentence type both had a significant effect on f_0: $F(2,676)=299.6$, $p<0.0001$ and $F(3,676)=64.2$, $p<0.0001$, respectively. It should be noted that although both Tone and Sentence were significant, there are fairly large differences between their F-values. That is, the factor Tone resulted in an F-value which is 4.6 times bigger the F-value of Sentence type. This means that the between-group variance of H, L, and HL tones exceeds the within-group variance (differences between speakers) to a larger degree than the between-group variance of the four sentence types. The interaction between Tone and Sentence type was non-significant:

$F(6,676)=1.6$, $p=0.142$. These results are visible in the plot below in Figure 3.9 of the interaction of the ANOVA model. There is a steep regression between f_0 and the three tones. Just as the scatter plot above in Figure 3.7 showed, there are high values for H tones, mid-level values for HL tones, and low values for L tone. The sentence types affect the steepness of these connecting lines between the data points. There is only one interaction here: the f_0 values for the H tones in *H_%* (solid line with circles) and *HL_HL* (dashed-dotted line with squares). Overall, the values of the three Sentence types *H_%*, *HL_HL*, and *M_L* are fairly close to each other, while *M_%* (dotted line with crosses) has the lowest f_0 values for all tones. It is visible that *M_L* and *HL_HL* almost overlap for HL and L tone. For the H tone, the difference is larger. In fact, as was shown in the previous section, the H tone was downstepped in *HL_HL* compared to in *M_L*.

	Df	Sum Sq	Mean Sq	F-value	Pr(>F)
Tone	2	1560.5	780.3	299.6	<2e-16 ***
SentenceType	3	502.1	167.4	64.2	<2e-16 ***
Tone:SentenceType	6	25.1	4.2	1.6	0.142
Residuals	676	671.9	0.99		
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					
aov(Midpoint_ST ~ Tone * SentenceType + Error(Speaker))					

Table 3.4: Results of Analysis of Variance.

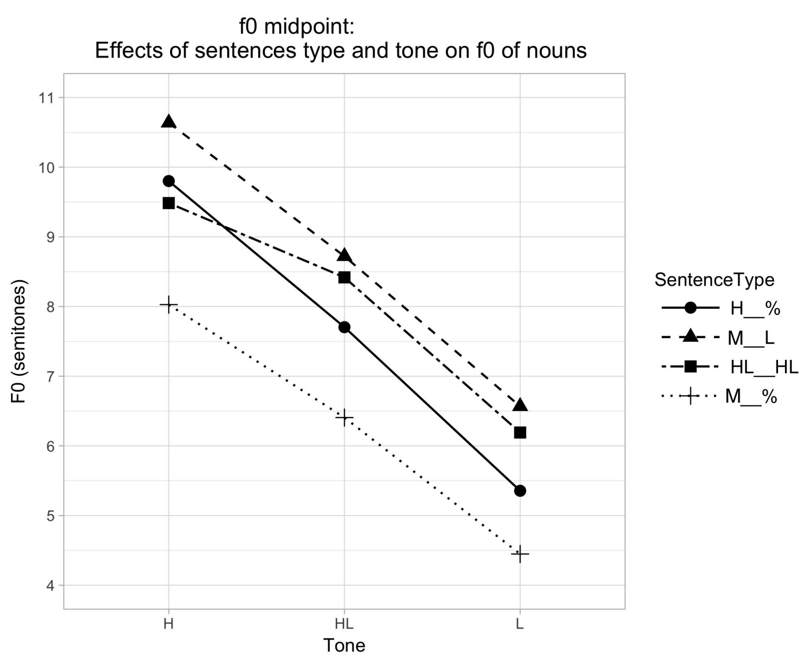


Figure 3.9: Effects plot of the ANOVA output: f_0 and factors Tone * Sentence type (model in Table 3.4). The f_0 measurements are at the midpoint of the nucleus in the target words.

The results of the pairwise T-tests are included in Table 3.5 (a–b) below to compare effects of the individual levels of Tone and Sentence type. In Table 3.5 (a), the contrastive tones H, L, and HL significantly differ from each other as expected (p<0.001). In Table 3.5 (b), not all Sentence types differ significantly from each other, and there are larger differences in how significant the interactions are. The sentence type *M_%* differs significantly from all sentence types. Moreover, *M_L* is significantly different from *H_%* (p=0.003) and highly significantly different from *M_%* (p<0.001). This was also visible in the plot of Figure 3.9 where *M_%* has the lowest values of f_0, and *M_L* has the highest levels. The Sentence type *HL_HL* is not significantly different from *H_%* (p=0.5) and *M_L* (p=0.4). However, the difference between *HL_HL* is highly significant from *M_%*.

	HL	L
L	< 2e-16	–
H	3.2e-11	< 2e-16
Formula: Midpoint ST $\sim$ Tone		

(a)

	H_%	M_%	M_L
M_%	0.00027	–	–
M_L	0.00327	1.0e-12	–
HL_HL	0.58938	8.5e-08	0.41003
Formula: Midpoint ST $\sim$ Sentence type			

(b)

Table 3.5: Pairwise comparisons using t-tests with pooled SD. P value adjustment method: bonferroni.

F_0 slope

The results of the slope are presented below. The interactions between Tone and Slope ST in Table 3.6 are significant (F(2,676)=148.3, p<0.001). The same applies to Sentence type: F(3,676)=74, p<0.001. The results are similar to the ones for Midpoint ST in Table 3.4 above. Also here the F-value is smaller for Sentence type. The difference is that the interaction between Tone and Sentence type on Slope are significant F(6,676)=4.2, p=0.0003. The F-value is very small for this interaction.

	Df	Sum Sq	Mean Sq	F-value	Pr(>F)
Tone	2	294.8	147.41	148.3	<2e-16 ***
SentenceType	3	220.7	73.58	74.0	< 2e-16 ***
Tone:SentenceType	6	25.3	4.22	4.2	0.000333 ***
Residuals	676	671.9	0.99		
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					
aov(Slope_ST $\sim$ Tone * SentenceType + Error(Speaker))					

Table 3.6: Results of Analysis of Variance.

Figure 3.10 illustrates these effects. The slopes differ greatly depending on the Tone. As was observed in section 3.3.1, HL tones always have the highest slope regardless of the Sentence type, while L tones come second. H tones have a small slope below or slightly higher than 1 ST. These differences can be observed in the plot as the factor Sentence type affects the slopes to a high degree: *H_%* is highest for all tones, followed by *M_%*, *M_L*, and *HL_HL*. The latter two interact for the H tone, where the slope is very shallow (below 1 ST).

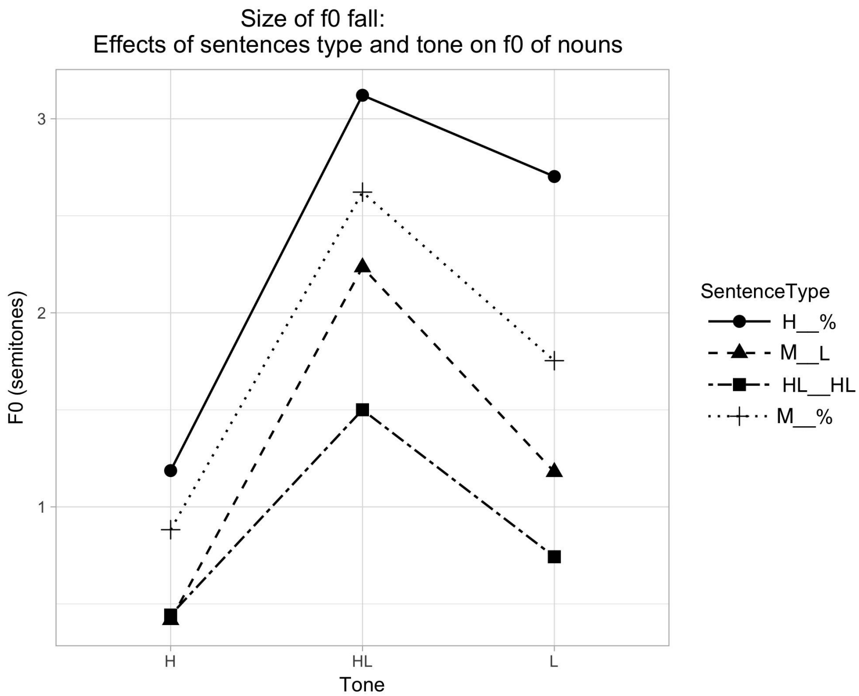


Figure 3.10: Effects plot of the ANOVA output: f_0 and factors Tone * Sentence type (model in Table 3.6). The f_0 measurements are of the size of the fall of the nucleus in the target words (f_0 in vowel onset minus f_0 in vowel offset).

The results of the T-tests of the factor interactions are shown in Table 3.7 (a–b). As expected, the interactions between Tone and Slope ST are highly significant in Table 3.7 (a) ($p<0.001$). In Table 3.7 (b), the differences between Sentence type and Slope ST differ in significance just as it did for Midpoint ST. Sentence type *M_%* is highly different from all other Sentence types: *H_%*, *HL_HL* ($p<0.001$), and from *M_L* ($p=0.007$). Sentence type *H_%* is also significantly different from the other types ($p<0.001$). Finally, the difference between *M_L* and *HL_HL* is significant but to a smaller degree than the other sentence types ($p=0.02$). These results confirm that the slope in nouns depends highly on Sentence type. It is perhaps surprising that the slope of the level tones differs from each other. The descriptive statistics, however, showed that L tones are phonetically not level, but falling. This applies to a small degree in sentence-medial positions, and to a large degree in sentence-final positions.

	H	HL
HL	< 2e-16	–
L	9.4e-10	1.6e-09
Formula: Slope ST ∼ Tone		

(a)

	M_%	H_%	HL_HL
H_%	0.0010	–	–
HL_HL	1.1e-08	< 2e-16	–
M_L	0.0074	1.9e-11	0.0263
Formula: Slope ST ∼ Sentence type			

(b)

Table 3.7: Pairwise comparisons using t-tests with pooled SD. P value adjustment method: bonferroni.

Discriminant analyses

Finally, the Linear Discriminant analyses showed that Midpoint and Slope (in z-scores) can predict the correct classification of tone (H, L, and HL) with 75.4% accuracy across all sentence types. This percentage is well above the chance-level baseline at 33%. When LDA was performed on tone for each sentence type separately, the percentages increased further to 80–85%. The results are shown in Table 3.8.

Sentence type	Correct classification result:
H_%	85.2%
M_%	80.3 %
M_L	85.5%
HL_HL	83.5%
All sentences	75.4%

Table 3.8: LDA results: Correct classification of tones on the bases of Midpoint and Slope (33% chance-baseline).

When tested separately, Midpoint and Slope were lower, but still above chance-level. Midpoint alone can predict the correct classification of tone with 65.6%, while Slope predicts the correct classification of tone with 58.1%. Thus, Midpoint is a better predictor than Slope in Nuer.

The correct classification for Sentence type by Midpoint and Slope was only 41.7% in comparison to 75.4%. This percentage is not much higher than the chance-level baseline at 25%.

3.4 Discussion

Before concluding, this section discusses some open issues on phonation and mid tones.

3.4.1 Phonation

Section 3.1.3 mentioned that breathy vowels might have lower f_0 than modal vowels. Unfortunately, it was not possible to control for this factor. In the data set – see section 3.2.1, the H tones were all breathy except for one noun. The HL tones, on the other hand, had only modal vowels. The results showed nevertheless that f_0 in breathy H-toned vowels contrast with HL or L tones. Thus, if phonation affects f_0, it does not lower breathy H tones to a degree which make them overlap with the other tones.

Table 3.9 presents the mean values and standard deviations of each noun by the six speakers of this study. Although there is only one modal noun, the values show that the modal H-toned noun *mɔ́n* 'soil' is at the same f_0 level as most of the breathy H-toned nouns. There is also a vowel height difference between these nouns because the breathy H-toned vowels have the low vowel ɛ̤́. Therefore, it would be expected that the breathy nouns have lower f_0 because of their phonation and their vowel height. This is not the case. The lower part of Table 3.9 shows the same values for L-toned nouns. The values go from 4.8 ST up to 6.4 ST. The lowest f_0 values are among the modal L-toned vowels, not the breathy ones. These values indicate that that breathy L-toned nouns are not lower than modal L-toned nouns in this study. Thus, the averaged values in Table 3.9 preliminary indicate that phonation might not lower f_0 in Nuer, at least not to a high degree.

Tone	Gloss	Noun	Mean ST (SD)	Voice quality
H tone	soils	mɔ́n	9.4 (2.5)	Modal voice
	crocodiles	ɲɛ̤́ˑŋ	9.4 (3.4)	Breathy voice
	eyes	wɛ̤́ˑŋ	10.21 (2.9)	
	gum	ɲɛ̤́ˑr	9.33 (2.5)	
	gums	ɲá̤ˑr	9.5 (3.1)	
	thief	wɛ̤́ˑn	9.0 (3.5)	
	thieves	wá̤ˑn	9.5 (3.3)	
	uncle	nɛ̤́ːr	9.1 (2.4)	
L tone	lion	lòɲ	6.1 (2.1)	Modal voice
	shaking	làt̪	4.9 (1.6)	
	girl	ɲàˑl	5.8 (2.5)	
	mosquito net	làˑŋ	5.0 (1.8)	
	relationship	màːr	5.1(2.3)	
	grass	wàːr	4.8 (2.1)	
	eye	wàŋ	5.8 (2.3)	
	cooked maize	ŋà̤ˑm	6.4 (2.7)	Breathy voice
	deep river	lò̤ˑl	5.6 (2.3)	
	mirror	nɛ̤̀ˑn	5.5 (2.1)	

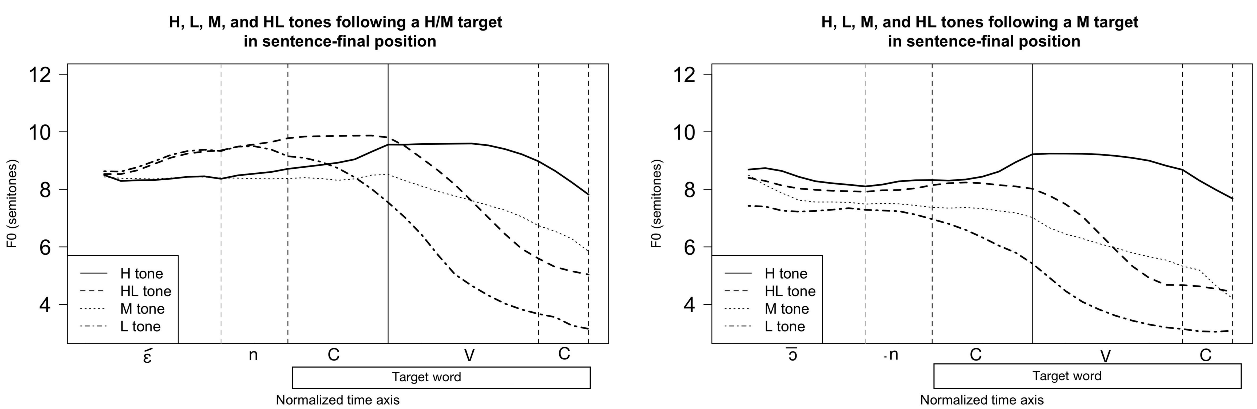
Table 3.9: Item-separate mean and standard deviations of f_0 midpoint (semitones) across all four sentence types by six speakers.

3.4.2 Mid-level tones

Two nouns were originally elicited in addition to the ones listed in table 3.1 but were not included because they differed from H, L, and HL tones: The nouns *lā̤ˑm* 'kind of fish' and *lâˑl* 'river stone'. The noun *lâˑl* has a free variation and alternates between falling, mid, and low, and its tonal realization appears to depend on the speakers. The noun *lā̤ˑm* has a fairly constant mid tone and is plotted below with the data from six speakers. For comparison, tokens of each speaker are also plotted using a H tone (*mɔ́n* 'soils'), a HL tone (*mâːr* 'my mother'), and a L tone (*là·ŋ* ‘mosquito net’).

In Figure 3.11a and 3.11b, the mid tone (dotted trace) is in the mid-range between the H tone (solid trace) and the L tone (dashed-dotted trace). It crosses over the HL tone (dashed trace) in approximately the middle of the nucleus. The mid tone declines towards the end of the nucleus in a similar manner to the H tone. It is also interesting to note the tone of the preceding syllable. In H_% in 3.11a, it is visible that the tone of the verb *nɛ·n* ‘see’ has a lower f_0 value in the nucleus before the H- and mid-toned nouns, compared to when it precedes the HL- and L-toned nouns. This is in line with the fact that the tone of this verb is realized a high before another L or HL tone, but surfaces with a mid tone before a H or mid tone.[1]

In the sentence type M_% in Figure 3.11b, the tone of the preceding syllable (*-kɔ̄n*) varies slightly depending on the tone, but only to a small degree. The variation appears to be phonetic in that the higher tones (H and HL) start a little higher, while the mid and L tone start slightly lower. Overall, it seems reasonable to consider this syllable mid-toned.



(a) Sentence type H_%

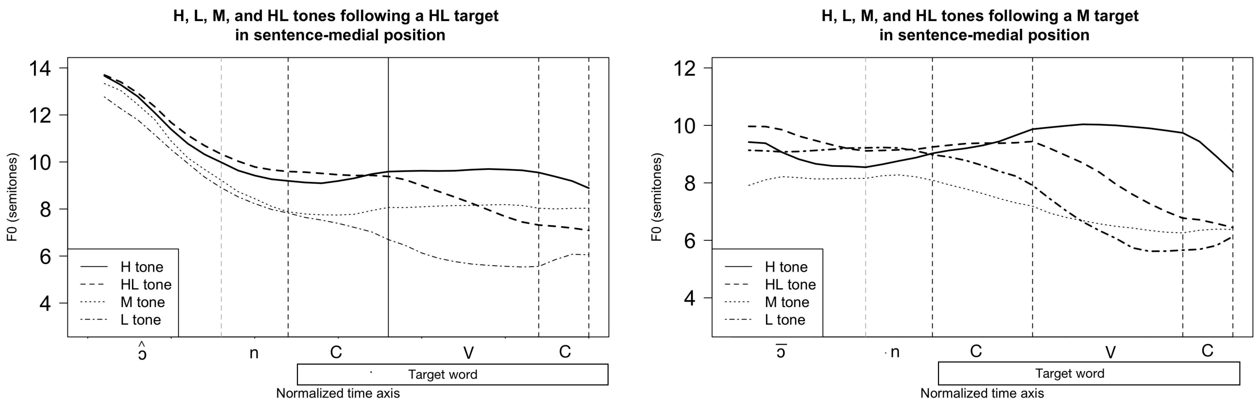
(b) Sentence type M_%

Figure 3.11

In the sentence type *HL_HL* in Figure 3.12a, the mid tone is also in the mid-range of the H and L tone. In the middle of the nucleus, it crosses the f_0 trace of the HL tone. The preceding syllable with a HL tone rises a little bit from the lowest point of the HL tone up to the mid tone. This confirms that the preceding syllable ends in a L target which is lower than a mid tone.

In Figure 3.12b, the preceding suffix *-kɔn* has a mid tone just as in the sentence type *M_%*. The tone of this suffix also varies to a small degree depending on the tone it precedes. The mid tone on the noun in *M_L* is not so clearly distinguished from the H and L tones. It falls lower than the suffix and appears to undergo declination in this context. This makes the mid tone overlap with the L tone.

[1] It is unclear whether the mid – high tone alternation on the verb is a phonetic effect or a sandhi process. It is also possible that the tone of the verb is always high and the following nouns are subject to upstep: H and mid-toned nouns are upstepped after H. Since the scope of this dissertation lies on nominal tone, further research is required to determine this.



(a) Sentence type HL_HL

(b) Sentence type M_L

Figure 3.12

3.5 Conclusion

This chapter reported results of the production of tone in Nuer. There is evidence of a phonetic contrast between H, L, and HL tones in monosyllabic nouns. These tones differ significantly in f_0 height and slope. Overall, HL tones have the steepest slope regardless of Sentence type. At the midpoint of the nucleus, the H tones are pronounced in the speaker's upper tonal space, the L tones are pronounced in the lower speaker's tonal space, and the HL tones are pronounced in the middle. The LDA indicated that Midpoint was a better predictor than Slope for Tone. Thus, the results indicate that f_0 height is a sufficient correlate to distinguish these tones in Nuer. The main difference between the HL and the L tones lies in the timing. After H and mid tones, the HL tones start to fall in the nucleus, while the L tone starts to fall in the onset. Thus, in this context, the timing of the fall distinguishes these two tones. These results indicate that lexical tone in Nuer has a significant effect on f_0. Each of the three levels (H, L, and HL tones) contrast from each other, and on this basis, the null hypothesis is rejected. The results indicate that tone in Nuer is phonetically contrastive.

Some nouns are found with a mid tone realization. The normalized f_0 plots showed that this tone lies in the mid-range of H and L tones. The data set had a bias of H-toned breathy vowels which was difficult to avoid due to the grammatical correlation between these two features. Ad-hoc examinations of mean and standard deviations showed that breathy voice does not lower f_0 to a degree which creates overlap with the other tones.

Tone in Nuer interacts with intonation. There is evidence of a phonetic final lowering which applies to the nucleus and coda of nouns in a sentence-final position. Here, the endpoint of the tones is lower compared to sentence-medial positions. Final lowering makes L tones falling in sentence-final position. F_0 is also affected by surrounding tones. In the sentence type *HL_HL*, which has a negative present form, the auxiliary *cí-kɔ̂n* has a higher pitch than the other tested sentences. This might be due to an upstep conditioned by the H tone of the negation-marking auxiliary. Regardless of this raised pitch, the L component of the HL tone in this auxiliary has a lowering effect on H tones. Therefore, it appears that HL tones induce automatic downstep on H tones. The sentence type *M_%* also showed a lowering effect, especially on H tones. In this sentence, the target words were pronounced utterance-finally following the high-mid-toned verb *nɛ́ˑn-kɔ̄n*. The status of this lowering effect is not entirely clear, and I leave it to future research whether the f_0 lowering after *nɛ́ˑn-kɔ̄n* depends on declination combined with final lowering, or whether this is a downstep effect in the sentence. In the sentence type HL_HL, there are actually three HL tones after each other when the noun has a HL tone, e.g., *cí-kɔ̂n wâːr nɛ̂ˑn* – see (57d). The data showed that the HL tones of the nouns have a shallower fall compared to the other three sentence-types. The measured slope was 1.49 ST, which is half the size of a fall compared to the same measurement in M_%. It is not clear whether the reduced fall of the HL tone alters the perception of this tone so that listeners perceive it as mid instead of falling. This question also remains open for further research.

Chapter 4

Perceptual cues of tones

Having established that nominal tone in Nuer differs significantly in f_0 production, this chapter presents perceptual evidence of lexical tone. I report the results of two perceptual experiments: one on f_0 height and one on f_0 alignment. Chapter 2 argued that Nuer has underlying H, L, and HL tones. Tones which contrast phonologically are expected to have a clear-cut perceptual distinction (D'Imperio, 2000). In the previous chapter, it was shown that H, L, and HL tones differ significantly in f_0 midpoint and slope. The LDA showed that midpoint is a better predictor for tone than slope. Indeed, the HL and L tones showed some amount of overlap in sentence-final position and are, therefore, the most interesting tonemes to test for perceptual contrasts. The goal of this chapter is (i) to show that HL and L tones differ perceptually in f_0 height and alignment, and (ii) to examine the critical thresholds for which Nuer listeners distinguish a HL tone from a L tone.

The experiment on f_0 height tests three minimal pairs differing in HL vs. L tones. The height of the tonal peaks is manipulated so that stimuli differ in semitones. The results show that listeners can distinguish between HL and L tones in isolation using only f_0 peak height as a phonetic cue. Nuer listeners demonstrated to have high sensitivity to this tonal cue by only needing 1.2 semitones (ST) to change perception from a L tone to a HL tone.

The experiment on tonal alignment tests the same minimal pairs from the f_0 height experiment, but the material differs in that the nouns follow a phonetic H target. The difference of these tones is encoded through the alignment of f_0 in relation to the nucleus of the target word which is measured in milliseconds (ms). The results indicate that HL vs. L tones in Nuer are easily distinguished by listeners when the timing of the fall is altered. This indicates that after a H target, alignment between tone and syllable boundaries is contrastive in Nuer. The location of perception crossover lies in the sonorous onset of a syllable. For one item, the perception shift happened after only 16 ms. The average threshold for the responses shifting from 20% to 80% across all items was 23 ms. This means that when the H target is located in the onset, as little as a 16 ms shift to the left towards the preceding target will make listeners change perception from a HL tone to a L tone.

Besides the methodological aspects of the study, the results are typologically surprising. The results of the experiments show that Nuer listeners are sensitive to very fine-grained changes of tonal height and alignment. The perceptual shift in f_0 height is inconsistent with the claim that only differences of more than 3 semitones are crucial in speech communication ('t Hart, 1981). More importantly, the results from the peak movement experiment show that the perceptual threshold for f_0 alignment in Nuer is much lower than observed in other studies. Studies on timing sensitivity in languages with lexical or post-lexical tonal accents show that timing sensitivity generally lies at 50 ms (House, 2004). These results indicate that listeners of a tone language such as Nuer are sensitive to much smaller differences compared to languages where tone is contrastive on the word or utterance level. These results are especially noticeable because Nuer speakers are not aware of speaking a tone language.

Another surprising outcome of this perception study is that the location of this crossover from L to HL tones lies in the sonorous onset of a syllable, not in the vowel. Based on these findings, the optimal tonal perception hypothesis by House (1990), which states that the optimal timing for a contour tone perception is 30–50 ms into the vowel, should be extended to sonorant onsets.

This chapter is structured as follows. In section 4.1, I present the research questions and give a background on f_0 height and alignment in perception. Section 4.2 outlines the methods of these experiments. In section 4.3 and 4.4, the results of both experiments are reported with summaries and discussions followed by the conclusion in section 4.5.

4.1 Background and research questions

The overall purpose of this phonetic study was to explore whether HL and L tones are perceptually contrastive. If speakers show a clear perceptual distinction of these two tones, it supports their contrastive nature in the phonology. Following Sudhoff et al. (2012), a typical result of categorical perception is a crossover from one category to another with a rise from less than 20% to more than 80% identification. The second aim is to examine the phonetic details of how listeners interpret the cues manipulated in these studies: f_0 height and alignment, which in chapter 3 were shown to be the primary acoustic correlates of tonal contrasts. That chapter showed that Nuer has final lowering which makes HL and L tones acoustically very similar in utterance-final positions. When following a phonetic H target, the main difference lies in the timing of the fall. By examining the perception of this cue, the goal was to test how many milliseconds separate the perception of a HL tone from a L tone. Related to this, the results indicate where in the syllable the peak must be aligned in order for listeners to hear a HL tone.

Concerning f_0 height, chapter 3 showed that the midpoint of HL and L tones differ by about

2 semitones. When tokens are pronounced in isolation, f_0 height is likely to play a role in distinguishing a HL tone from a L tone. That is, a L tone is expected to lack a f_0 peak, whereas HL tones are expected to have a reference value of f_0 as they involve a glide movement from one tone target to another. Since final lowering in Nuer gives L tones a falling contour in isolation, it is not clear how listeners can distinguish a HL tone from a L tone in Nuer. In this context, it was tested whether f_0 height alone could separate a HL tone from a L tone.

Cross-linguistically, the answers obtained in this study differ from other studies, especially on f_0 alignment. The results shed light on the thresholds of f_0 height and alignment of falling tones in Nuer, and serve to enrich the general discussion of perceptual boundaries of tone. The remainder of this section discusses important literature on the perception of f_0 height and alignment manipulations.

4.1.1 F_0 alignment

A widely discussed question in studies of suprasegmental levels of speech concerns the temporal alignment of f_0 in relation to segmental boundaries. In f_0 alignment experiments, the prevailing results are that listeners are not sensitive to differences of less than 50 ms when identifying between tone X and tone Y (House, 2004).

Studies on the perception of peak shift on falling contour tones have established that the main difference between a falling tone and a L tone lies in the timing of the fall in relation to the vowel onset. Generally, studies on tonal alignment concern "[...] the temporal synchronization of tones and segments" (D'Imperio, 2000: 10). When the f_0 peak is manipulated on a time-axis to the left and right of a target segment, listeners' perception typically shifts between the meaning X/Y of a minimal pair. In this kind of task, the meaning X corresponds to one extreme of the f_0 alignment, and meaning Y corresponds to the other extreme of the manipulation.

To illustrate, consider the Figure below in 4.1. As Remijsen and Ayoker (2014) observe, a tone which follows a high f_0 target will be perceived as either low, falling, or high depending on the timing of the fall. When the fall of a tone takes place during the onset of a syllable (trace A), this will be perceived as a low tone. If the tone falls in the nucleus, either at the vowel onset (pattern B) or more into the nucleus (pattern C), the tone will be perceived as falling because, perceptually, the movement happens within the most salient part of the syllable, namely the vowel. If the tone falls during the coda, it will be perceived as a high tone (pattern D).

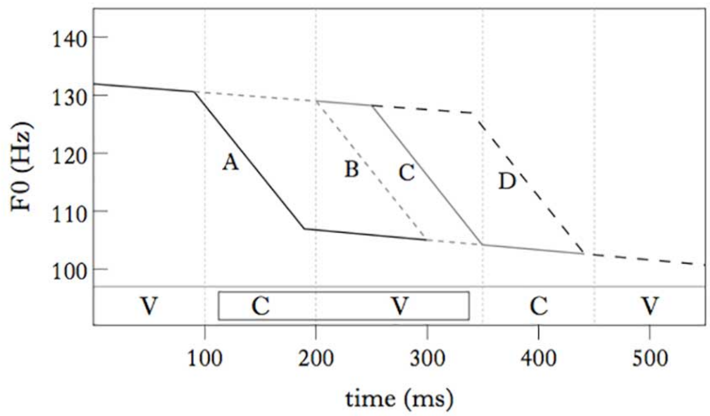


Figure 4.1: Figure taken from Remijsen and Ayoker (2014: 436) on in Shilluk showing patterns of alignment of tonal patterns within the syllable.

Segmental boundaries

In perception studies of tonal alignment, it has been reported that listeners pay attention to f_0 turning points located in the mid- or end region of a syllable. House (1990) proposes a model of optimal tone perception which relates pitch perception to the amount of new spectral information in a syllable. He reports that tonal movement early in the vowel, an area of spectral discontinuities (e.g., rapid formant transitions, consonant release, and intensity jumps) is perceived as a level pitch, while tonal movement later in the vowel, an area of spectral stability, corresponds to a contour tone. His findings are that pitch sensitivity decreases with increased spectral information in the signal. He suggests that the optimal timing for a contour tone perception is 30–50 ms into the vowel. Concretely, a tone which starts to fall in the consonant onset and through the vowel onset is predicted to be perceived as L, a tone which starts to fall about 30 ms into the vowel is expected to be perceived as HL, and a tone which falls late in the vowel and into the syllable coda is expected to be perceived as a level H tone.

In addition to the midpoint of the vowel as the perceptive salient locus for tone alignment, House (1996) finds that the end of a syllable can also be perceptually salient in f_0 alignment. Results from his study on tonal perception in Thai (see House and Svantesson 1996) show that falling tones can be located in the sonorant coda of a syllable and still be perceived as a fall. Based on these results, he concludes that besides spectral information, syllable structure also matters in that tonal perception at the end of a syllable is greater compared to other positions.

Different studies support these findings. For example, the study by Zsiga and Nitisaroj (2007) shows that Thai listeners are inclined to perceive a tonal target at the end of a syllable. A recent study by Kelly and Smiljanić (2017) show that listeners used the H tone in accent 2 in Norwegian only when it was aligned 48 ms (28%) into the vowel. In the study by Verhoeven (1994) on tone perception in Dutch, he tested stimuli with an early continuum and a late continuum of f_0 alignment. In the former, the pitch fall was located in the prevocalic consonant of the syllable, while in the latter, the location of the pitch fall was located in the spectrally stable portion of the signal. The overall results showed that items with the early continuum had a longer time of uncertainty compared to items with a later standard. He concludes that these results are in line with House's optimal tone perception model.

Thus, existing studies on segmental boundaries and tonal alignment show that pitch sensitivity is highest in areas distanced from the vowel onset towards the middle of the vowel. In addition, the syllable position matters; the sonorant coda also is a salient locus for pitch perception.

Timing thresholds

Beyond the language-specific goals for this study, there are two reasons why the perception of tonal alignment is interesting to examine in Nuer. The first reason is that f_0 alignment is understudied in tone languages such as Nuer, where tone is contrastive at the syllable level, and f_0 alignment has primarily been examined in languages where tone is contrastive at the utterance level. A well-known case is Neapolitan Italian where the contrast between a statement and a question is marked by tone alignment. In questions, the alignment of a H target is later than in statements. The difference in timing sensitivity lies at approximately 70 ms (D'Imperio and House, 1997). For other languages where tone mainly matters at the level of intonation, studies show that listeners are sensitive to timing differences of 50 ms for German (Kohler, 1987) and 60 ms for English listeners (Pierrehumbert and Steele, 1989).

Several f_0 alignment studies have also been conducted on languages which restrict tonal contrasts to stressed syllables (Norwegian, Swedish, Dutch, etc.). The importance of f_0 alignment as a perceptual cue has been established for Swedish and for some dialects of Norwegian. The main outcome is that the two 'lexical accents' (accent 1 and 2) differ acoustically and perceptually in the timing of the peak (Bruce, 1977; Bruce and Gårding, 1978: among many others). The results of the perceptual threshold of time sensitivity are mixed here. In an early study by Bruce (1977), he shows that peak shifts result in either an accent 1 or accent 2 interpretation. Listener's discrimination indicates a low timing threshold of around 30 ms. However, as Remijsen (2013c) notes, these results may not fully represent the timing sensitivity of Swedish listeners because the f_0 excursions of the stimuli exceeded the limits observed in production (over 8 ST for durations from 40–80 ms). In fact, later studies have shown very different results: around 100 ms in Bruce (1983) and between 50–60 ms in Gårding and Eriksson (1991).

When comparing Swedish with Norwegian, the recent study on Norwegian by Kelly and Smiljanić (2017) has again very different outcome. In their study, f_0 maximum, among other cues, was manipulated in 22 ms steps. Listeners did not show a clear-cut in accent interpretation, and the results showed that the responses never reached 100%. This gave identification curves which were gradual rather than abrupt in the tone perception of Norwegian listeners.

In Dutch, Verhoeven (1994) altered the fall- and rise-alignment in steps of 10 ms in an AX discrimination task. The point where the discrimination curve crossed 50% was taken as the measure of the listeners' alignment sensitivity. He concluded that the mean threshold for fall alignment is 70 ms.

There are also studies on f_0 alignment in tone languages. However, most of these studies have been conducted on East and Southeast Asian languages. The results are mixed, for example, Gårding et al. (1986) conducted a perception study on discrimination between tone 3 and tone 4 in Mandarin with different manipulation cues. One involved a timing shift of f_0 peaks in steps of 32 ms. The results showed a categorical shift in only one step indicating a timing sensitivity of 32 ms. In the study by Shen and Lin (1991) on the perception of Mandarin tone 2 and 3, manipulations in the f_0 alignment were done for two continua which differed in the steepness of the slopes (15 vs. 30 Hz). The results differed for these two continua in that listeners showed a faster category shift in the f_0 alignment on the steeper continuum (2 manipulation steps which corresponded to 62.2 ms) compared to the shallower continuum (3.5 manipulation steps). The results correspond to a timing sensitivity of 65,2 ms for a steep continuum.

There are only a few studies on the perceptual cues of other kinds of tone languages. Recently, there has been reported study on Itunyoso Trique (Oto-Manguean language spoken in Mexico) by DiCanio (2012), a study on Medʉmba (Grassfield Bantu) by Franich (2016), and a study on Sesotho (Southern Bantu) by Mixdorff et al. (2011). The two former studies do not directly involve f_0 alignment manipulations, and the study by Mixdorff et al. (2011) involves the perception of level tones only.

In summary, there is a considerable gap in the literature on perceptual thresholds of f_0 in tone languages such as Nuer, where tone is contrastive at the syllable level. Nuer is also an appealing language to examine because of its neighboring languages, which have unusual contrasts in falling tones. The languages Dinka and Shilluk have fine-grained differences in falling tones. Recall the two falling patterns (B) and (C) in Figure 4.1 above. They illustrate a very unusual contrast between two types of falling tones within the nucleus in Dinka. The study by Remijsen (2013c) reports two falling tones which contrast in f_0 alignment (Fall and Low$^{\text{fall}}$). The results of a production study show that these tones differ in the timing of the peaks by 30–50 ms. There are short, mid, and long vowel stems which, are contrastive in Dinka. In short vowel stems, the difference between the two tones is the smallest with a mean of 30.9 ms (Remijsen, 2013c: 319). A similar contrast is found in Shilluk between early- and late-aligned High-falling tones (Remijsen and Ayoker, 2014).

In Dinka, the narrow contrast in tone alignment is argued by Remijsen (2013c) to be perceptually salient. In a small-scale perception experiment with a forced-choice design, Remijsen shows that Dinka listeners are able to discriminate between the lexical and morphological meanings which these two falling tones express, even for short vowels. This perception experiment indicates that the claimed threshold of 50 ms for the perception of time alignment in languages examined until now (cf. House 2004) appears to be lower for listeners of languages like Dinka. As Remijsen observes, this is in accordance with recent studies showing a direct connection between tonal complexity in a language with the ability of pitch discrimination in that “[...] pitch processing is fine-tuned during the acquisition of a tone language” (Pfordresher and Brown, 2009).

The connection between native language and the degree of pitch perception has not only been found in Dinka. In the cross-linguistic perception study by Gandour and Harshman (1978), a number of tone cues were tested for listeners of English, Thai, and Yoruba. One of the many outcomes of this study were that *direction* (positions of the tone peak on a time axis) was one of the main cues which affected listeners responses of the tones. Even more importantly, the participants speaking tone languages (Thai and Yoruba) had an opposite pattern in the responses for this cue. Namely, the Thai and Yoruba listeners were significantly more responsive to the cue *direction* compared to the English listeners.

On a similar note, Giuliano et al. (2011) report the results of an experiment testing the ability of pitch discrimination of Mandarin native speakers and a control group of non-tone speakers. The results show that speakers of a tone language are more accurate pitch discriminators than speakers of a non-tone language.

In sum, when establishing perceptual thresholds of f_0 alignment, the results are fairly mixed. The generalization of 50 ms by House (2004) appears to be a value which represents listeners of stress accent languages and tonal languages with a restrictive inventory. It is hard to make generalizations for tone languages, mainly because they do not extend to many languages beyond East and Southeast Asian languages. This makes it difficult to estimate how many milliseconds listeners are sensitive to in f_0 alignment shifts. The contrastive HL tones in Shilluk and Dinka indicate that these languages are typologically different from other tone languages indicating fine-grained differences in the tonal inventory prevailing in Western Nilotic languages.

4.1.2 F_0 height

The role of f_0 height in tonal perception is an understudied topic. Most studies on differential thresholds in pitch height focus on intonation languages, languages with restricted tonal inventories, or East Asian tonal languages. An examination of comparative studies on f_0 in non-speech suggests that pitch perception depends on language background. Such studies have shown that speakers of a tone language perform better on dimensions which are linguistically relevant in the lexical tone of their native language. For example, Mandarin speakers are better at detecting slope differences in f_0 compared to English speakers. On the contrary, English speakers are better than Mandarin speakers on detecting f_0 height differences (see Jongmana et al. 2017 and further references therein). Studies on f_0 height show that listeners are sensitive to differences in pitch as small as 0.3–0.5 Hz in non-speech or speech-like signals (Flanagan and Saslow, 1958; Klatt, 1973). In this context, speakers of a tone language do not have an advantage in pitch discrimination (Bent et al., 2006; Francis and Ciocca, 2003; Burnham et al., 1996). On the contrary, there is evidence that speakers of non-tonal languages actually perform better than speakers of tonal languages (DiCanio, 2012).

In speech perception of f_0, the differential thresholds have large discrepancies. There are many studies on the Just Notable Difference (JND). This refers to the smallest detectable change in a stimulus signal.[1] In languages with restricted tonal inventories, 't Hart (1981) tested dynamic pitch perception among Dutch listeners. Although the results varied strongly according to the listeners, the outcome indicated higher sensitivity for rising tones than falling tones. The time of uncertainty was 3.2 ST for overall speech rises (JND 1.6). For falling tones, the time of uncertainty was higher: 4.2 ST (JND 2.1). As 't Hart points out, this difference might be due to the exposure of native Dutch speakers to rising tones in their language. The study concluded that 3 semitones or more is needed for listeners to perceive a tone change in speech communication.

In a similar study, Rietveld and Gussenhoven (1985) report a lower differential threshold for pitch height in Dutch. Based on their results, they conclude that 1.5 ST is sufficient for Dutch listeners to perceive a difference of prominence in accents. In both studies by 't Hart (1981) and Rietveld and Gussenhoven (1985), the experiments involved listeners judgments of prominence between two accents which differed in f_0 height. As Rietveld and Gussenhoven (1985) mention, it remains an open question whether 1.5 ST has categorically distinct levels, or if it is gradient in nature.

For studies on the Just Notable Difference (JND) in languages with lexical contrastive tone, results differ. In Hong Kong Cantonese, the two rising tones T2 and T5 are merged by some young speakers. Mok and Wong (2010a) show that listeners who merge these tones in their production also have difficulties in perceiving a contrast between them. Interestingly, their study shows that not only the mergers but also speakers who do not merge these tones had difficulties in perceiving the difference between T2 and T5. These two tones have the same starting point and differ only in about 10 Hz in their f_0 minimum. In the degree of the rise, they differ in approximately 20 Hz in the f_0 maximum they reach (Mok and Wong, 2010b). It is possible that the overall difficulty for distinguishing these two tones is simply due to the sound change in Hong Kong Cantonese and is independent of their acoustic features. However, because the control group also had difficulties in distinguishing them, it is perhaps more probable that the merging of these tones happens precisely because they are so similar. This leads to the question of how much tonal space is needed for tones to be perceptually distinguished. The

[1]It is calculated by dividing the ambiguity time between responses by the value of the stimulus.

study by Silverman (2003) reports a surprising small JND. It shows that only 9 Hz is required for listeners to discriminate complex tones of modal voice. However, as Kuang (2012) notes, this is perhaps an exception, and phonological contrasts in tone usually require much bigger differences than 9 Hz.

Studies show that it becomes increasingly difficult for listeners to distinguish tone in languages with more than three tone levels. For example, Connell (2002) tested the perception of four level tones in Mambila, a Bantoid language spoken in areas of the borderland between Nigeria and Cameroon. The study shows that Mambila listeners had difficulties with the two tones, T2 and T3, which are in the middle range. In ten steps of 5 Hz, listeners could choose between four near minimal pairs corresponding to four different level tones embedded in carrier sentences. From the identification task, the results indicate that the highest and lowest tones were easily identified. The two tones in the middle, however, mostly did not reach more than 60% correct identification. The same task was tested with English speakers. Surprisingly, the results show that the Mambila listeners are not more sensitive than English listeners to pitch differences. This shows that perceiving contrasts between four tone levels and beyond is hard for listeners and does not seem to be easier for native speakers of a tonal language.

For languages with more tone levels, other cues come into play to facilitate pitch perception. For example, in the five-level tone language Black Miao, Kuang (2012) shows that the tones 22 [–upper, H] and 33 [+upper, L] are the most difficult to distinguish by listeners compared to the other tones. These tones differ in about 20 Hz in f_0 height, and phonation is a vital cue to distinguish them, and tone 33 is pronounced with a breathy voice quality.

To summarize, the results of studies on the perception of pitch height differ widely. Older studies of Dutch show a sensitivity around 3 semitones. In tone languages, a categorical perception is not always obtained as in Mambila. In studies with tones which are similar in the production such as in Black Miao, these tones are also difficult to perceive, and other cues besides f_0 come into play.

4.2 Methods

4.2.1 Material

The material used for these experiments were six nouns corresponding to three minimal pairs. In the f_0 alignment experiment, the stimuli were nouns uttered in a sentence. In the f_0 height experiment, the stimuli were nouns pronounced in isolation. The material was produced by a 38-year-old female speaker of the Gajaak tribe of Eastern Jikany Nuer who came from Gambela town.

F_0 alignment

Early vs. late alignment was tested by manipulating the timing of the f_0 peak. The stimuli were three minimal pairs following a H-toned target: the imperative verb *nɛ́ˑn* 'look at' (62)–(64).[2] The segments in the crucial areas of alignment are sonorant: the coda of the verb and the onset of the nouns. Note that for the noun *lat̪*, the coda is pronounced with a fricative: [lâθ] – see section 1.1. The meaning this noun in the sentence in (63b) may refer to is, e.g., an earthquake.

(62) *Minimal pair of /maːr/*

a. nɛ́ˑn mâːr
see.IMP.SG my.mother
'Look at my mother!'

b. nɛ́ˑn màːr
see.IMP.SG relationship
'Look at the relationship!'

(63) *Minimal pair of /lat̪/*

a. nɛ́ˑn lâθ
see.IMP.SG cotton
'Look at the cotton!'

b. nɛ́ˑn làθ
see.IMP.SG shaking
'Look at the shaking!'

(64) *Minimal pair of /waːr/*

a. nɛ́ˑn wâːr
see.IMP.SG sheep.dung
'Look at the sheep dung!'

b. nɛ́ˑn wàːr
see.IMP.SG grass
'Look at the grass!'

The figures 4.2a–4.2f below show the segmentation boundaries and the pitch contours of the original tokens prior to manipulation. It is visible that the peak of the fall in HL tones are aligned exactly at the onset of the vowel, i.e., at the boundary between the consonant onset and the vowel.

[2] The tone of this verb is M when it precedes a H tone but H when it precedes a HL and L tone – see chapter 3.

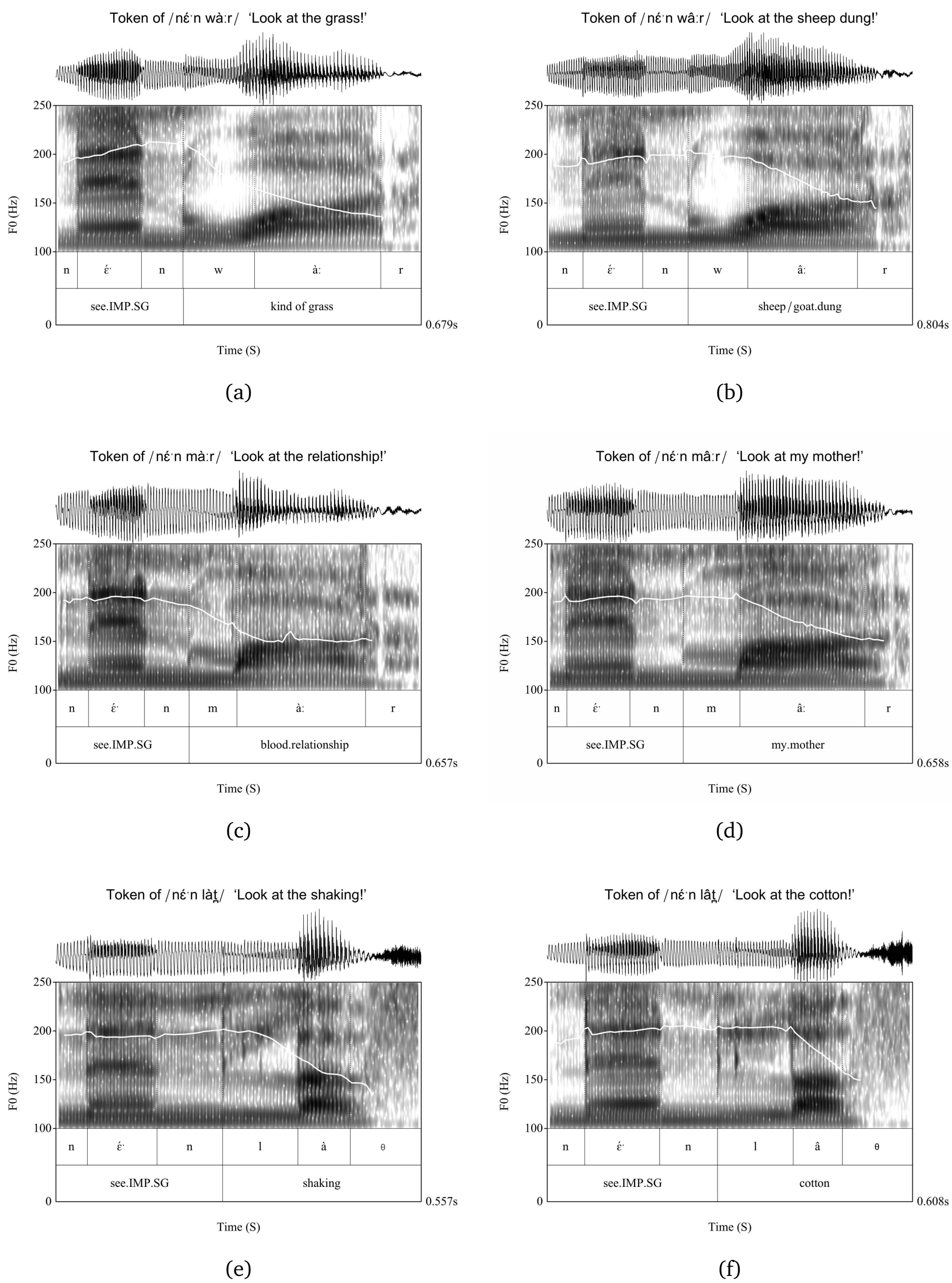


Figure 4.2: Original tokens of stimuli.

It could be expected that because of the duration differences between the items, the f_0 peak would be located more into the vowel for *maːr* and *waːr* compared to the item *la*θ which has a short vowel, but this is not the case. Instead, it is the slope which differs between the items. Table 4.1 shows the size of the f_0 falls and the duration of the vowels of the original tokens prior to manipulation. The f_0 fall for 'cotton' corresponds roughly to the overall mean of the slope of HL-toned nouns in the production study which was 3.1 ST for six speakers – see H_% in Table 3.2 of the previous chapter. The duration of the other two items are longer, and as expected the f_0 fall is about 1 ST larger.

Item – Gloss	Dur (ms):	f_0 fall (ST)
*lâ*θ – 'cotton'	74.7	3.70
mâːr – 'my mother'	224.6	4.52
wâːr – 'sheep dung'	242.0	4.49

Table 4.1: Token values of the three items with HL tone used for manipulation. The f_0 slope was calculated using the difference in ST between the f_0 measured at the end and at the beginning of the vowel.

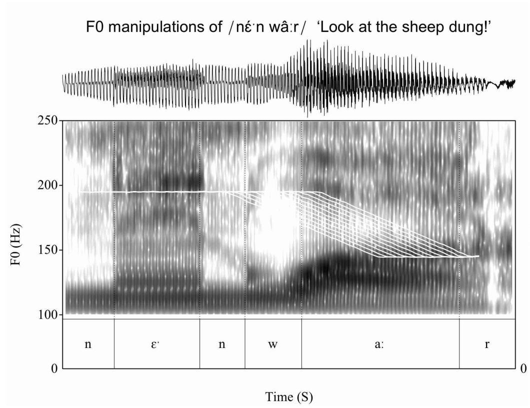
In order to keep all variables in the stimuli constant, the duration of the coda of the verb and the onset of the item were manipulated to obtain a fixed duration. The values were based on the production of the speaker: 70 ms for the coda /n/ of *nɛ́n* and 75 ms for the onset of the item (/w/, /m/ or /l/). The manipulations were made in the duration tier of the manipulation objects in Praat (Boersma and Weenink, 2016). Duration points were set at each boundary and 5 ms distanced from these targets. In addition, two duration points were set for the coda and onset, which were manipulated to the corresponding values.

For the manipulations of the alignment, all pitch points were removed in the manipulation tier in Praat, and three new pitch points were added: one at the beginning of the vowel of *nɛ́ˑn*, one at the beginning of the vowel of the item, and one at the end of it. The alignment was shifted in steps of 15 ms as shown in Table 4.2. Seven steps leftwards to the H-target (early alignment) and two steps rightwards to the vowel (late alignment). Step 0 was at the very beginning of the vowel.

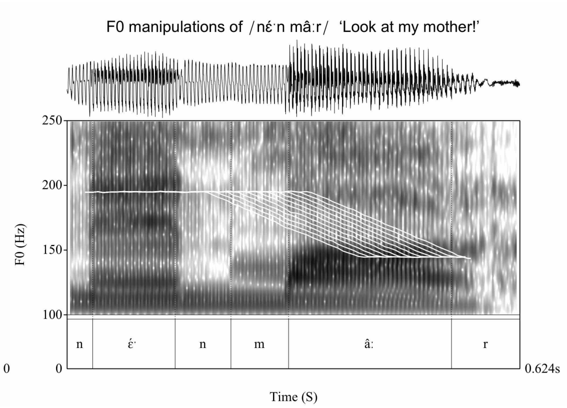
Location of f_0 peak:	Preceding H target:			Target noun:							
	Coda			Onset					Nucleus		
Steps in ms:	−120	−105	−90	−75	−60	−45	−30	−15	0	15	30

Table 4.2: Manipulation steps in milliseconds in relation to the onset-nucleus boundary at 0 ms.

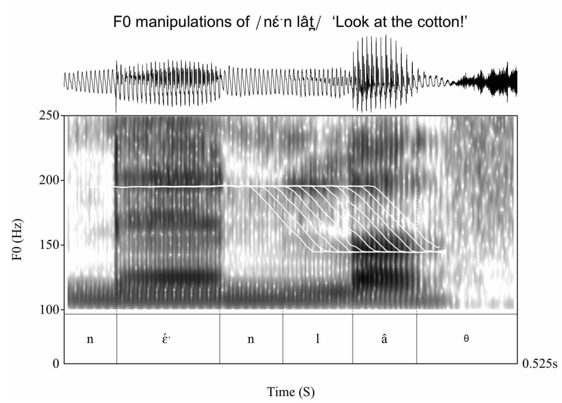
The pitch contour alignments of each manipulation step are shown in the figures 4.3a–4.3c below. There were 11 manipulations in total for each item. The first point was kept constant while the two latter were shifted in the alignment manipulations so that the slope would remain constant. For the item *la*θ, the last part of the vowel before the unvoiced fricative [θ] had an absence of formant structure which might indicate a glottalization. The second pitch point was set at the end of the stable, high-intensity part of the vowel rather than at the final part of the segment where the formant structure was lacking. This boundary follows segmentation guidelines of Turk et al. (2006) where segmentation is set at the locus where the F2 energy is critically damped.



(a)



(b)



(c)

Figure 4.3: Stimuli for f_0 alignment experiment. 11 manipulation steps of alignment.

F_0 height

The three minimal pairs of the f_0 alignment experiment were also the stimuli for the f_0 height experiment. The three nouns were pronounced in isolation (65)–(67). The original tokens of all six nouns are shown below in the figures 4.4a–4.4f.

(65) a. mâːr
'my mother'
b. màːr
'relationship'

(66) a. lâθ
'cotton'
b. làθ
'shaking'

(67) a. wâːr
'sheep/goat dung'
b. wàːr
'kind of grass'

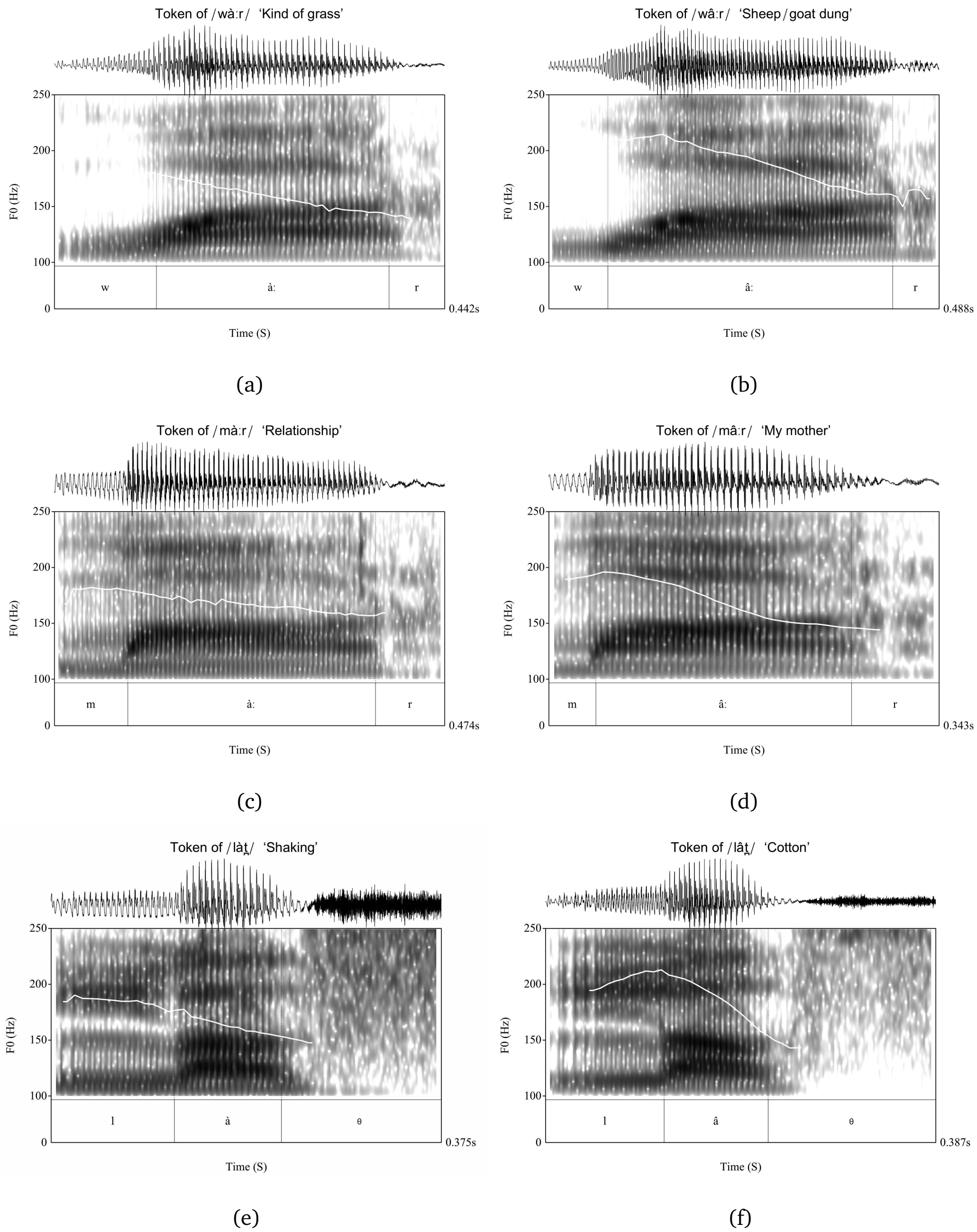


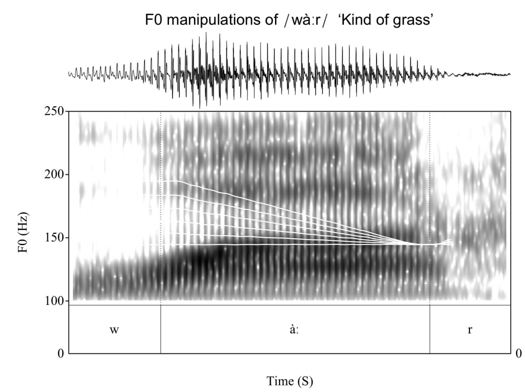
Figure 4.4: Original tokens of stimuli.

As illustrated in Figure 4.4, all tokens have a falling contour even though there is no H target preceding the items. This makes the L tones fairly similar to the HL tones. The main difference between the items lies in the peak, as the initial height of the fall is higher for the HL-toned nouns than for the L-toned nouns. The f_0 height stimuli were prepared in Praat by manipulating the PitchTiers. All pitch points were removed, and two new pitch points were set to the values 200 Hz (beginning of V) and 150 Hz (end of V). The difference in the f_0 range was calculated in ST (4.98 ST rounded up to 5 ST). The first pitch point was manipulated by increasing the f_0

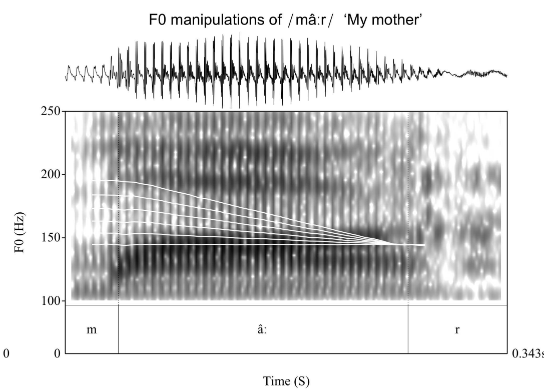
height in semitone steps. There were six steps starting at 0 (150 Hz) and increasing incrementally up to 200 Hz with one ST per step, as shown in Table 4.3. The semitones were calculated in Praat: hertzToSemitones(150) = 7.019. The figures 4.5a–4.5c show the segmental boundaries where the pitch points were set at each level of the f_0 peak manipulations. For item [laθ], the second pitch point was set right before the reduced formant structure of the vowel started.

Steps	Hz	Semitones
0	150	7.019
1	158.9	8.019
2	168.3	9.019
3	178.3	10.019
4	188.9	11.019
5	200.2	12.019

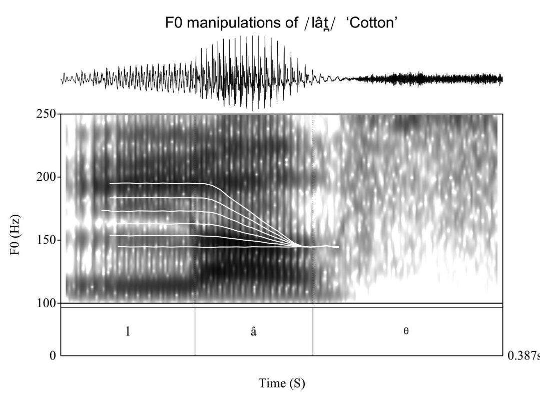
Table 4.3: Steps of the f_0 height manipulation with 1 semitone differences.



(a)



(b)



(c)

Figure 4.5: Stimuli of f_0 height experiment. 6 manipulation steps differing by 1 ST (150–200Hz).

The reason for including step 0 was the fact that L tones in Nuer have an entirely flat contour when following a L target in sentence-medial position. In comparison, HL tones do have a falling contour after a L target, but the f_0 height is lower compared to when it follows a H tone.

4.2.2 Listeners

There were 33 participants in the f_0 height experiment (31 males, 2 females). Apart from one, all participants also took part in the f_0 alignment experiment: 32 participants (30 males, 2 females). The majority were in their twenties (min age: 21, max age: 56). The listeners spoke mainly the Eastern Jikany dialect of the Western Ethiopian area and came from Gambela town or near it. Most commonly they came from the Gajaak or Gajiök tribe. Of the 33 participants, there were 11 Gajaak, 11 Gajiök, three Gaguang, and one Thien – see section 1.1. Three participants spoke Lou, a dialect of the Eastern area of South-Sudan.

4.2.3 Procedure

The listeners participated in quiet rooms at two different Universities and at SIL Ethiopia, all located in Addis Abeba. They were seated in front of a laptop with headphones. It was an identification task, and the stimuli were presented with the Experiment MFC script in Praat. Each stimulus was presented in random order using <PermuteBalancedNoDoublets>, an option that randomizes the stimuli ensuring that the same stimulus never appears twice in a row. Each manipulated token was presented for the listener sequentially. Once the sound file was played, they were asked to choose between the two meanings of the minimal pairs.

In the f_0 height experiment, the stimuli were presented in three blocks with pauses in between. There was a replay button available on each frame in case the listeners did not hear the stimulus well the first time. The six manipulation steps were repeated three times for each item. This resulted in 54 tokens. The experiment took 5–7 minutes. Figure 4.6 shows how the experiment was presented.

For the f_0 alignment experiment, the same procedure was used. The stimuli were played for the listener sequentially and they then had to choose between the two meanings of the relevant minimal pair: Look at X vs. look at Y. In the experiment, the 11 manipulation steps were repeated three times for each item. This resulted in 99 tokens. There were 6 blocks with pauses in between. The experiment took 7–10 minutes. The listeners participated first in the f_0 height experiment. They then had a break between 5–10 minutes before they participated in the falling tone alignment experiment.

Prior to both experiments, there was a training phase in which a mixed set of the stimuli were presented to familiarize the listeners with the task. The training phases lasted about 1–3 minutes.

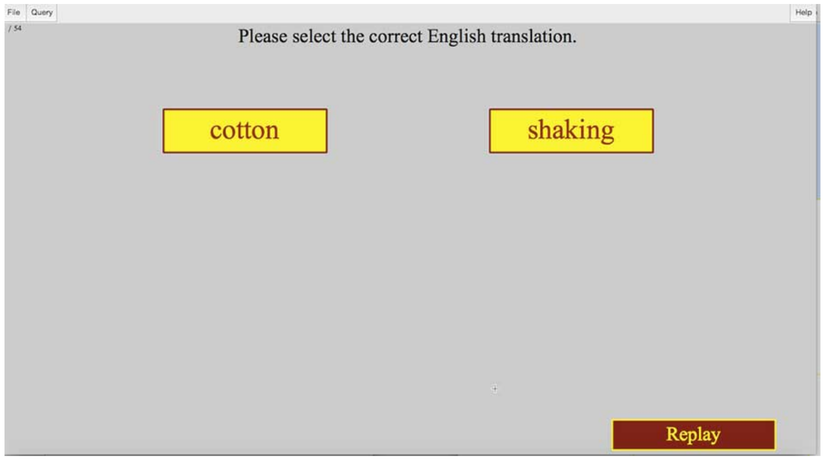


Figure 4.6: Experiment procedure: A forced choice task for identification of minimal pairs of HL and L tones.

4.2.4 Analyses

The responses were analyzed by comparing how the manipulation of semitones and milliseconds affected the perception of HL vs. L tones. Psychometric curves were plotted in R with the package *ggplot2* (Wickham, 2016) to show how the slope of the responses changed for the manipulation steps. In order to determine the overall effect of the manipulations and other factors on the responses, a polynomial regression model was run with the *glmer* function in *R* (package lme4 version 1.1-12, developed by Bates et al. 2015). The dependent variable for both experiments was Response tone (HL or L). Independent variables were: (i) f_0 Alignment for the first experiment (measured in ms); (ii) f_0 Height for the second experiment (measured in ST); and (iii) Stimulus with the levels *wa:r, ma:r* and *la*θ. Listener was included as a random factor.

The polynomial model was necessary because of the non-linear structure of the regression in the data, e.g., when there is a linear relation up until a certain breaking point where the slope of the regression line suddenly changes. The number of 'knots' used in the model control the number of breaking points in the regression. 4 knots were used, i.e., four breaking points in the regression. The choice of 4 knots was decided after a model comparison in ANOVA: 4 knots was significantly better compared to 3 knots, whereas five knots created oversmoothing of the data points.

The polynomial model could calculate the perceptual thresholds of the responses. In R, it was calculated how many milliseconds and semitones it took for the listeners to shift perception from a L tone to a HL tone according to the following criteria. In psychophysical studies, the threshold set for the difference threshold, or the Just Noticeable Difference, can be set at 20% and 80% of listeners perception. These are somewhat conservative limits, and often 75% and 25% are often used. When the responses for the HL tone are below 20%, the responses are categorized as a L perception. When the responses of HL tones are above 80%, the responses are categorized as HL perception. The time between 20–80% is the uncertainty interval.

4.3 Results and discussion of f_0 alignment

In both experiments, two participants performed at chance level and their results were, therefore, disregarded.[3] This left 30 participants for the f_0 alignment.

4.3.1 Results

The results indicate an abrupt shift from L to HL responses. The raw data are first shown in the psychometric curve in Figure 4.7. It shows the percentages of HL responses at each manipulation step averaged across all listeners. The change in responses can be observed from −120 ms (early alignment/L tone) to 30 ms (late alignment/HL tone). From −120 to −90 ms, the HL responses are fairly low, as expected (below 15%). All three items have a steep curve, but the item *la*θ has the steepest one. For this item, it is visible that until −45 ms, the responses for HL tones are very low (below 7 %). From this point on, the HL responses increase abruptly. For the other two items, the curve for the HL responses is also steep but slightly less compared to *la*θ.

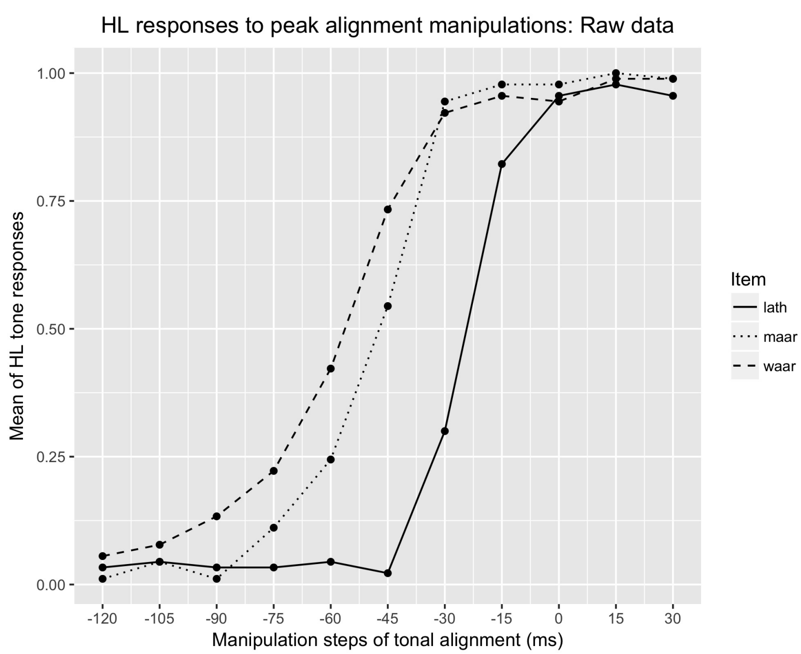


Figure 4.7: Percentage of HL responses as a function to f_0 alignment manipulations (ms).

[3]It was clear during the trial that these two participants did not understand the task. Concerning their background, these two participants did not stand out from the rest. They were both male, aged 27 and 31 and belonged to the most represented dialect and tribe among the participants: Jikany and Gajaak/Gajiök. One was from the rural area of Ethiopia at the border to South-Sudan while the other was from Gambela in Ethiopia.

The results of the polynomial logistics regression model are shown below in Table 4.4. The main effects of f_0 Alignment on Response tone were significant for all 4 knots when the intercept was the Stimulus *la*θ (poly (Alignment,1–4): p<0.001). The interactions between *la*θ–*maːr* and between *la*θ–*waːr* were both highly significant in the main effects (p<0.001). The effects of these interactions are shown for the knots 1–4. For the interactions between *la*θ–*maːr* and *la*θ–*waːr*, all knots have significant effects (p<0.001) except for when there are 3 knots (p=0.58 and p=0.11, respectively).

The table also shows the interactions with *maːr* and *waːr* as intercepts. The interaction between *maːr* and *waːr* were overall non-significant (p=0.40). These results confirm the graph of the raw data in Figure 4.7 where the curves for stimuli *maːr* and *waːr* have a similar shape compared to *la*θ which stands out by being steeper.

Concerning the effects for each knot from 1–4, when *maːr* and *waːr* are the intercepts, 2 and 4 knots are non-significant. Only 1 and 3 knots are significant (p<0.001). This indicates that 4 knots are necessary for item *la*θ, but not for the other two items. If the data set would only contain stimuli *maːr* and *waːr*, 3 knots would have been sufficient to capture the non-linearity of the responses.

The choice of 4 knots in the polynomial regression model was compared with the same model with 3 knots in ANOVA. The results in Table 4.5 justifies the choice of 4 knots: Compared to 3 knots, the model with 4 knots is significantly better ($p < 0.001$). Increasing the knots to 5 was avoided because it resulted in oversmoothing of the data.

Formula: ResponseTone∼poly(Alignment, 4) *Stimulus+(1 | Listener)

Fixed effects:	Estim.	S.E	z	Pr(>|z|)
(Intercept = laθ)	-0.90	0.24	-3.71	0.000205 ***
poly(Alignm, 4)1	169.71	9.79	17.33	< 2e-16 ***
poly(Alignm, 4)2	53.11	8.78	6.04	1.46e-09 ***
poly(Alignm, 4)3	-45.26	8.65	-5.22	1.71e-07 ***
poly(Alignm, 4)4	-48.49	9.15	-5.30	1.16e-07 ***
Stimulus laθ/maːr	1.58	0.28	5.55	2.77e-08 ***
Stimulus laθ/waːr	1.81	0.22	8.13	4.07e-16 ***
poly(Alignm, 4)1:Stimulus laθ/maːr	42.21	17.63	2.39	0.016700 *
poly(Alignm, 4)2:Stimulus laθ/maːr	-59.62	14.99	-3.97	6.99e-05 ***
poly(Alignm, 4)3:Stimulus laθ/maːr	-7.47	13.73	-0.54	0.586272
poly(Alignm, 4)4:Stimulus laθ/maːr	32.26	14.83	2.17	0.029573 *
poly(Alignm, 4)1:Stimulus laθ/waːr	-10.56	14.14	-0.74	0.455009
poly(Alignm, 4)2:Stimulus laθ/waːr	-60.87	13.08	-4.65	3.28e-06 ***
poly(Alignm, 4)3:Stimulus laθ/waːr	19.10	12.19	1.56	0.117143
poly(Alignm, 4)4:Stimulus laθ/waːr	52.47	12.38	4.23	2.25e-05 ***
(Intercept = maːr)	0.67	0.29	2.26	0.02339 *
poly(Alignm, 4)1	211.98	14.32	14.80	< 2e-16 ***
poly(Alignm, 4)2	-6.45	11.45	-0.56	0.57294
poly(Alignm, 4)3	-52.72	9.94	-5.30	1.15e-07 ***
poly(Alignm, 4)4	-16.25	10.84	-1.49	0.13412
Stimulus maːr/waːr	0.23	0.28	0.82	0.40793
poly(Alignm, 4)1:Stimulus maːr/waːr	-52.88	17.01	-3.10	0.00188 **
poly(Alignm, 4)2:Stimulus maːr/waːr	-1.35	14.95	-0.09	0.92790
poly(Alignm, 4)3:Stimulus maːr/waːr	26.52	12.67	2.09	0.03641 *
poly(Alignm, 4)4:Stimulus maːr/waːr	20.22	12.68	1.59	0.11079
(Intercept =waːr)	0.91	0.25	3.58	0.000341 ***
poly(Alignm, 4)1	159.15	12.67	12.56	< 2e-16 ***
poly(Alignm, 4)2	-7.75	10.45	-0.74	0.458054
poly(Alignm, 4)3	-26.15	9.11	-2.87	0.004091 **
poly(Alignm, 4)4	3.98	8.31	0.48	0.631323

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 4.4: Generalized linear mixed model fit by maximum likelihood: Polynomial model with 4 knots.

Models	Df	AIC	BIC	logLik	dev.	χ^2	χDf	Pr(>χ^2)
poly3	13	1443	1521	-708	1417			
poly4	16	1417	1513	-692	1385	32	3	5.2e-07 ***

Table 4.5: Results of ANOVA test of two models: Polynomial with 3 knots vs. 4 knots. The test favors a polynomial model with 4 knots.

The effects are plotted in Figure 4.8. It visualizes the effects of the polynomial glmer model in Table 4.4 above. The 4 knots allow for a non-linear curve which fits the data.

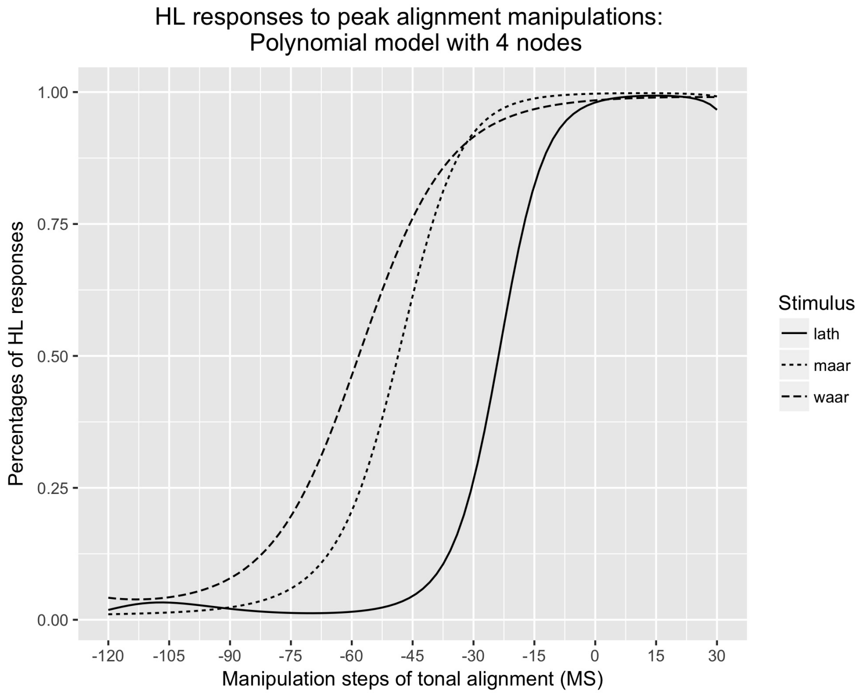


Figure 4.8: Effect plot of the polynomial model (see Table 4.4). The percentage of HL responses as a function of Alignment manipulations (ms).

The calculations of the boundaries for the perception threshold are shown in Table 4.6. As confirmed in the ploynominal model, the results differ according to the stimuli. For responses of HL which are up to 20%, the stimuli are mostly perceived as L-toned. This was obtained approximately 30 ms before the nucleus boundary (−32.2 ms) for *la*θ. For the other two items, 20% of HL responses were obtained at −60.2 ms for *maːr*, and at −74.6 ms for *waːr*. For HL responses above 80%, the stimuli are mostly perceived as HL. For Stimulus *la*θ, this boundary was obtained at −15.8 ms. This differs greatly from the other two items. Here the same boundary was obtained at −37.9 ms (*maːr*) and at −42.2 ms (*waːr*). The time of uncertainty, i.e., the time it took for the listeners to shift from 20% to 80%, is surprisingly small. For item *la*θ, it took as little as 16.3 ms. The same shift took 22.3 ms for item *maːr* and 32.3 ms for item *waːr*. The mean of these values are 23.6 ms with a standard deviation of 8 ms.

Percentages of HL responses:			
20%:	80%:	80%–20%: Time of uncertainty	Stimulus
−32.2 ms	−15.8 ms	16.3 ms	laθ
−60.2 ms	−37.9 ms	22.3 ms	maːr
−74.6 ms	−42.2 ms	32.3 ms	waːr
laθ/maːr/waːr			
−55.7 ms	−32.0 ms	23.6 ms	means
21.5 ms	14.1 ms	8.0 ms	sd

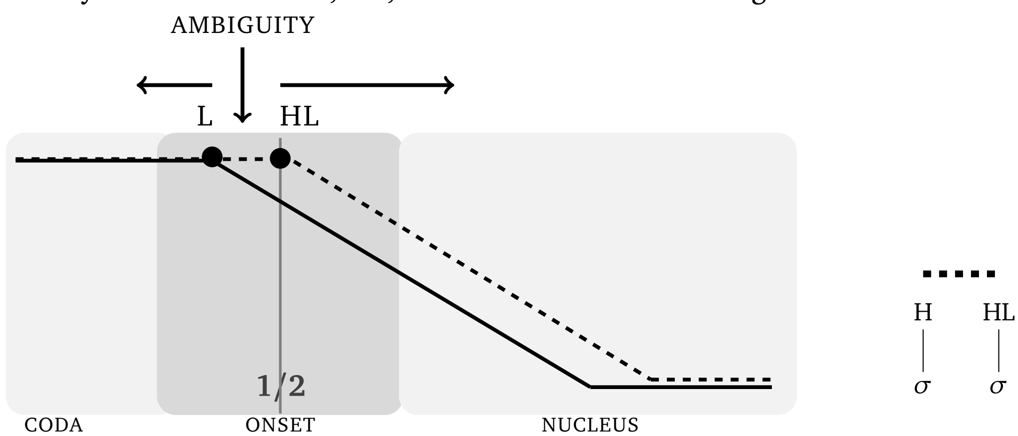
Table 4.6: Perceptual threshold of tone alignment. The number of milliseconds it took for participants to shift from a 20% response to an 80% response of HL identification.

4.3.2 Summary and discussion

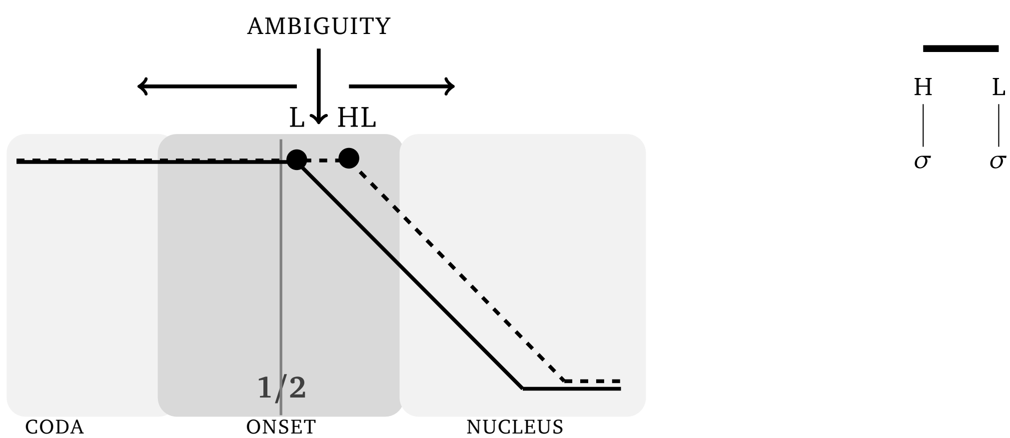
The results indicate that Nuer listeners can clearly distinguish a HL from and L tone perceptually. Although a discrimination task is needed, this experiment indicates that listeners might have a categorical perception of these tones based on the 80-20% crossover. The listeners managed to perceive the difference between a HL from a L tones with high accuracy. The time of uncertainty was surprisingly low with an average of 23 ms. The results of the polynomial model with 4 knots captured the non-linear effects of the responses. That is, the curve of the psychometric graph and the polynomial model were very steep because the HL responses were first low, indicating L responses. Then, there was a sudden shift to high HL responses which increased towards 100%. This change in responses was captured with the polynomial model. Moreover, the model showed that the effect of f_0 Alignment was significant. The responses differed depending on the items. The item *laθ* was significantly different from *maːr* and *waːr*, and a change from L tone to HL tone was obtained in only 16 ms for *laθ*. Differences between *maːr* and *waːr* were non-significant in the polynomial model. The time it took for responses to change from L to HL for these items were higher, at 22 and 32 ms, respectively. It is unusual that listeners' perception of tone alignment is so sensitive to changes in manipulations. The numbers indicate that the generalization made by House (2004), namely that the threshold for identifying f_0 alignments normally lies at 50 ms, should be extended to include lower thresholds.

Alignment of HL tones

The results show that there is a critical point in the onset where the peak of a f_0 target needs to be located in order for Nuer listeners to perceive a HL tone. The exact location in the onset differs depending on vowel length. This is shown schematically in Figure 4.9 below. It illustrates where HL tones are perceived (80%≥ HL responses) and where L tones are perceived (20%≤ HL responses). Figure 4.9a shows the location for long vowels (*maːr* and *waːr*), and Figure 4.9b shows the location for the short-vowel item *laθ*. Note that this schema is possible because the duration of the onset was set to a standard duration in all the stimuli. For long vowels, the earliest point where a HL tone is perceived (dashed line) in relation to the nucleus is halfway into the onset. From this point and rightwards, until the peak is located into the vowel, listeners perceive a HL tone. For L tones, the latest point (20%≤ HL responses) where they can be perceived as such is 4/5 distanced away from the nucleus. L tone perception continues to increase up to almost 100% the further to the left the peak is aligned. It is an essential point that both L tone and HL tone perception is possible when the peaks are located in the onset. For short vowels, the critical points which determine HL or L perception are close to the boundary of the nucleus. The latest point where L tone is perceived is near the middle of the onset. The earliest point where a HL tone can be perceived (80%≥ HL responses) is very close to the nucleus, 1/5 away from the nucleus, i.e., 20% into the onset starting from the nucleus.



(a) Alignment in long vowels (*ma:r, wa:r*)



(b) Alignment in short vowel (*la*θ)

Figure 4.9: Schematic representations of the results of alignment of HL and L tones after a H target based on perceptual responses. In nouns with long vowels (Figure a), HL responses (dashed line) are obtained at earliest when the peak is aligned approximately halfway into the onset, while L tone responses (solid line) are obtained when the peak is aligned about 1/5 into the onset. There is ambiguity when the alignment is between these points. For short vowels (Figure b), HL responses are obtained when the peak is located 4/5 into the onset, and L tone responses are obtained at a little over 1/2 away into the onset.

The time of uncertainty is between the latest point where L tones can be perceived and the earliest point where HL tones can be perceived. As the figure illustrates, these points are very close to each other. The major finding is that the period of uncertainty is only between 22–32 ms for long vowels and 16 ms for short vowels.

Moreover, the schematic representation in Figure 4.9 shows that f_0 movement for Nuer listeners is detectable near the onset-nucleus boundary. That is, in HL tone perception, most of the f_0 fall happens in a region with rapid spectral change. Considering the optimal tone perception model of House (1990), this is a new result. In addition to the timing boundary 30–50 ms into the vowel proposed by House, Nuer shows that it is possible to have a timing boundary in the sonorant onset. It is in this area of the onset that Nuer listeners perceive the f_0 peak. These results show that listeners do not only pay attention to the final part of the vowel or at the beginning of the sonorant coda as has been shown for Thai, but f_0 information in the sonorant onset of the syllable can also be salient. This indicates a possible language-dependent syllable saliency of f_0 perception.

For Nuer specifically, these results show that HL tones are early aligned and the fall starts in the onset of the syllable. The f_0 peak of HL tones can be located in the area of the syllable onset regardless of the duration of the vowels. For all items, approximately 80% of the fall needs to be located in the nucleus in order for a HL tone to be perceived. Because there is a vowel length difference between the items (short vs. long vowel), this indicates that the internal structure of the syllable, i.e., the mora, does not have a direct relation to the f_0 contour. If this were the case, it would be expected that the timing differences of the peak would be within the vowel (see Xu 1998 for a discussion of this).

Differences between items

Regarding the differences between the items, a significant effect was found between *laθ–maːr*, and between *waːr–laθ*, but not between *waːr* and *maːr*. The most plausible explanation for this lies in the differences between the slope of the fall of the items.

The three minimal pairs differ in vowel length and coda type. This affects the slope of the f_0 falls in the manipulations. As was shown in Table 4.1, the items *maːr* and *waːr* have long vowels: 224 ms and 242 ms, respectively, while the item *laθ* has a short vowel: 74 ms. As was mentioned in section 4.2, the slopes of the manipulations were set uniformly at 5 ST for all items. A 15 ms shift in the manipulation is perceptually more salient over a short vowel compared to a 15 ms shift of a f_0 contour over a long vowel. For the noun *laθ*, a 15 ms shift of HL alignment corresponds to 20% of the entire vowel. In comparison, a 15 ms shift in the HL alignment in *waːr* and *maːr* corresponds to only 6% of the vowels (6.1% and 6.6%, respectively). Therefore, the magnitude of the manipulation steps is greater under higher time pressure, i.e., for the item *laθ* compared to the items with less time pressure (*waːr* and *maːr*). This might make the manipulations of alignment more salient to the listeners under bigger time-pressure compared to smaller time-pressure. It would follow from this that the listeners have a shorter time of uncertainty for *la*θ compared to the other two items because of this salience. That is, only one step in the manipulations is sufficient for the listeners to detect a change in alignment. It is different for the items *waːr* and *maːr* because one manipulation step corresponds to only a small part of the f_0 contour, and two or three steps are needed for the listeners to detect a change in tone.

Thus, under higher time-pressure, it appears that Nuer listeners are more sensitive to f_0 alignment manipulations compared to under lower time-pressure. For the former, as little as 16 ms is needed in order for listeners to perceive a tone shift from L to HL. This is in line with the study by Shen and Lin (1991) mentioned in section 4.1.1 in which the timing threshold differed for the two kinds of continua of manipulations: a steep and a more shallow. The steeper continuum obtained a lower perceptual threshold than the shallower continuum.

Concerning the production of falling tones, HL tones tend to be preferred in environments which correspond to items such as *waːr* and *maːr*, and not environments such as *la*θ. The study by Zhang (2002) reports that the syllable rhymes which typically license a contour tone are long vowels, sonorant codas, stress, and postlexical lengthening. For Dinka, Remijsen (2013c) found that the size of the fall in two contrastive falling contours differs according to the type of coda (sonorant vs. plosive) and the degree of vowel length of the nucleus. The results support the claim in 2, namely that contour tones in Nuer are not restricted to environments with a long vowel and/or with only sonorous codas.

The slope of five semitones over 74 ms in the stimuli of this experiment might be considered typologically unusual. It is expected that time-pressure leads to a smaller size of f_0 fall. In Xu (2002) and Xu and Sun. (2002), they find that speakers need on average 124 ms to realize a falling contour tone of four semitones. One might wonder whether the stimuli of this experiment are ecologically valid. Recall from section 4.1.1 that the results of Bruce (1977), where Swedish listeners were sensitive to a timing difference of around 30 ms, might not be ecological valid because it exceeded the limits observed in the production (see a discussion by Remijsen 2013c on this). In the manipulations, the f_0 excursions of the stimuli were 8 ST for vowel durations of 40–80 ms.

For this study, I argue that the stimuli reflect the production of the female speaker and speakers with a high register. This speaker also participated in the production data of the previous chapter. When examining the realization of the HL tones in nouns with a short vowel, this speaker starts fairly uniformly at 200 Hz in the preceding H target and the HL fall reaches a L target at around 150 Hz (7.0 Semitones). This goes for the five tokens, *jâ*ŋ 'cow', ɲ*ân* 'kind of grasshopper', *mân* 'mother', *mâ*ŋ 'wave', and lâθ 'cotton'.

When examining f_0 for all speakers in the production study in these five nouns with a short vowel, the slope of the short-vowel items vary greatly among speakers, and some have an unusually steep slope in the production. The overall average value for HL tones on the five items with a short vowel is 2.5 ST with a standard deviation of 1.4 ST. When examining these subsets of the data further, it shows that two speakers with a high register, i.e., the female speaker who produced the perception stimuli, and another male speaker, have the mean value 4.1 ST with a standard deviation of 1.1 ST. Both produce items with slopes of 5 ST. In comparison, a subset of the other four speakers gives the mean value of only 1.7 ST with a standard deviation of 0.7 ST. They have a lower register compared to the former two speakers. These examinations indicate that some Nuer speakers have steep falls over short time spans. I argue that since the female who produced the material for this perception study, generally have falling contours of 5 semitones on short vowels, the stimuli simply represent this speaker's realization of falling tones. This steepness seems to have an impact on the perception since listeners are sensitive to a very small degree of change in the timing.

It is interesting that in Nuer, falling tones can have nearly the same size of fall compared to long vowels, at least for some speakers. This might be a way to keep short HL vowels with a fall perceivable. In his study on Dinka, Remijsen (2013c) found that short vowels with a voiceless coda affect the f_0 alignment of falling tones in that it conditions a leftward shift on the peaks (i.e., earlier in the nucleus towards the onset). The size of these falling tones is below the Glissando threshold, and these tones ('Mid tonemes') alternate with a L tone on short vowels with a voiceless coda in the Bor North dialect of Dinka. This is interpreted as a natural development of contour tones which turn into level tones when realized in non-optimal environments for f_0 fall (short vowel and voiceless codas). The steep falls in shorter vowels like *la*θ in Nuer indicate that HL falls are maintained in all environments in this language. The responses of the experiment also show that listeners have no problem with hearing a HL tone on a short vowel item with a voiceless coda.

4.4 Results and discussion of f_0 height

As was mentioned in section 4.3, the results of two participants were excluded because they performed at chance level. This left 29 participants for the f_0 height experiment.

4.4.1 Results

Overall, the results show that the 29 listeners were highly accurate in identifying the HL-toned items at the higher end of the scale (4–5 ST) and the L-toned items at the lower end of the scale (0–1). Figure 4.10 shows the percentages of HL responses at each manipulation step averaged across all listeners with psychometric curves. The change in responses can be observed from 0 semitones (manipulation corresponding to a L tone) and up to 5 semitones (manipulation corresponding to a HL tone). From 0–1 semitone, the HL responses of all items are below 14%. At 2 ST, the stimuli of *maːr* and *waːr* have HL responses below 25%, and the curve rises steeply with overlap between the two items. Stimulus *la*θ differs from *maːr* and *waːr* as it increases for HL responses after only 1 semitone. Overall the curve for this item is slightly less steep compared to the other two items. The curve flattens out at step 4–5 for all stimuli where the HL responses are above 90%.

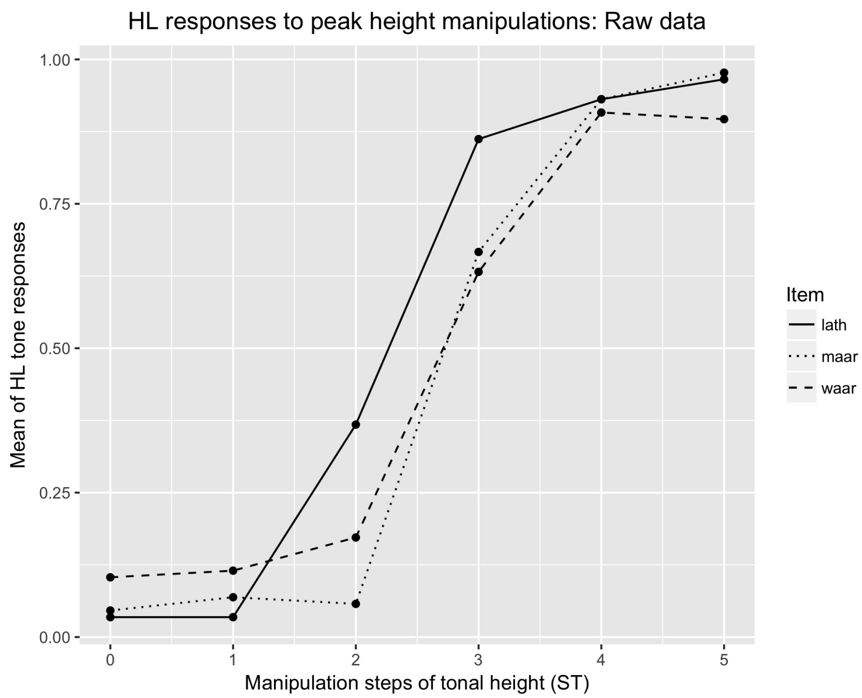


Figure 4.10: Percentage of HL responses as a function to f_0 height manipulations (ST).

The results of the polynomial regression model are given in Table 4.7 below. A model with 3 knots was used. The main effects in the correlation between Response tone and f_0 Height + Stimulus were significant for the knots 1 and 3 ($p<0.001$) when the intercept was the Stimulus *la*θ. The differences in responses between the stimuli *la*θ and *maːr*, and between *la*θ and *waːr* were non-significant ($p=0.178$ and $p=0.165$). When *maːr* was the intercept, the correlation between Response tone and f_0 Height + Stimulus were significant for all 3 knots. The interaction between *maːr* and *waːr* was non-significant ($p=0.828$). This interaction was only significant for one knot ($p<0.001$), but not for 2 or 3 knots ($p=0.182$, and $p=0.643$). Finally, when *waːr* was the intercept, 1 and 3 knots were significant in the correlation between Response tone and f_0 Height + Stimulus ($p<0.001$) but not 2 knots ($p=0.1$).

The choice of a polynomial model with 3 knots is justified in model comparisons in ANOVA. The results are shown in Table 4.8. A model with 3 knots is significantly better than 2 knots ($p<0.001$), but 4 knots did not improve the model ($p=0.057$). As with the f_0 alignment model, 5 knots was avoided because of oversmoothing.

Formula: ResponseTone~poly(ST, 3) *Stimulus+(1 | Listener)				
Fixed effects:	Estim.	S.E	z	Pr(>|z|)
(Intercept = laθ)	-0.15	0.19	-0.80	0.41859
poly(ST, 3)1	-103.85	9.57	-10.84	< 2e-16 ***
poly(ST, 3)2	13.51	7.73	1.74	0.08040 .
poly(ST, 3)3	20.33	7.20	2.82	0.00475 **
Stimulus laθ/maːr	0.37	0.27	1.34	0.17816
Stimulus laθ/waːr	0.32	0.23	1.38	0.16545
poly(ST, 3)1:Stimulus laθ/maːr	-1.05	13.21	-0.08	0.93648
poly(ST, 3)2:Stimulus laθ/maːr	-33.21	10.93	-3.03	0.00239 **
poly(ST, 3)3:Stimulus laθ/maːr	5.67	10.49	0.54	0.58881
poly(ST, 3)1:Stimulus laθ/waːr	32.21	11.16	2.88	0.00392 **
poly(ST, 3)2:Stimulus laθ/waːr	-21.61	9.24	-2.33	0.01934 *
poly(ST, 3)3:Stimulus laθ/waːr	1.43	8.90	0.16	0.87204
(Intercept = maːr)	0.21	0.19	1.10	0.268313
poly(ST, 3)1	-104.91	8.94	-11.72	< 2e-16 ***
poly(ST, 3)2	-19.70	7.20	-2.73	0.006241 **
poly(ST, 3)3	26.01	7.53	3.45	0.000559 ***
Stimulus maːr/waːr	-0.05	0.23	-0.21	0.828280
poly(ST, 3)1:Stimulus maːr/waːr	33.26	10.47	3.17	0.001490 **
poly(ST, 3)2:Stimulus maːr/waːr	11.60	8.70	1.33	0.182300
poly(ST, 3)3:Stimulus maːr/waːr	-4.24	9.17	-0.46	0.643793
(Intercept = waːr)	0.16	0.13	1.27	0.20376
poly(ST, 3)1	-71.64	5.71	-12.53	< 2e-16 ***
poly(ST, 3)2	-8.10	4.93	-1.64	0.10040
poly(ST, 3)3	21.76	5.34	4.07	4.64e-05 ***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

Table 4.7: Generalized linear mixed model fit by maximum likelihood: Polynomial model with 3 knots.

Models	Df	AIC	BIC	logLik	dev.	χ^2	χDf	Pr(>χ^2)
poly 2	10	1090.3	1143.9	-535.17	1070.3			
poly 3	13	1061.4	1131.0	-517.68	1035.4	34.97	3	1.231e-07 ***
poly 3	13	1061.4	1131.0	-517.6	1035.4			
poly 4	16	1059.9	1145.6	-513.9	1027.9	7.48	3	0.057 .

Table 4.8: Results of ANOVA tests of models: Polynomial with 3 knots is significantly better than 2 knots, but 4 knots is not better than 3.

In Figure 4.11, the effects of the polynomial model from Table 4.7 is shown. It visualizes the overlaps between the curves of stimuli *maːr* (dotted line) and *waːr* (dashed line). The curve of Stimulus *la*θ (solid line) is also quite close to the two former stimuli. This confirms the results in Table 4.7 where none of the interactions of the stimuli were significantly different from each other, except for some interactions specific for each knot. Nevertheless, the curves of *maːr* and *waːr* are steeper than the curve of *la*θ.

The perceptual boundaries were calculated with the polynomial model. The results are shown in Table 4.9. For stimuli *maːr* and *waːr*, HL responses at 20% (mostly perceived as L tone) were obtained when the f_0 peak was at 2.2 ST and 1.9 ST, respectively. The Stimulus *la*θ obtained the same boundary at 1.6 ST. When HL responses were at 80% (mostly perceived as HL), the stimuli *maːr* and *waːr* hardly differed (3.3 ST and 3.4 ST, respectively). The Stimulus *la*θ obtained this percentage of HL responses when the peak was 2.8 ST high. It took only 1.1 ST and 1.2 ST for the stimuli *maːr* and *la*θ to change from a L to a HL response. The Stimulus *waːr* only differs minimally from them with 1.5 ST for the time of uncertainty. On average, it took 1.2 ST for all the stimuli to change from L to HL.

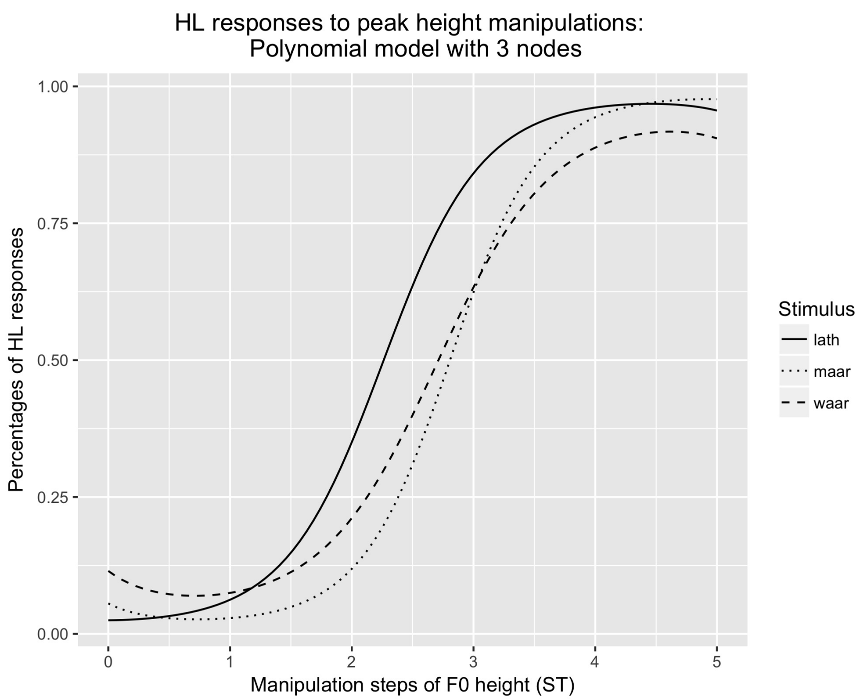


Figure 4.11: Effect plot of the polynomial model (see Table 4.7): The Percentage of HL responses as a function of to f_0 alignment manipulations (ms).

Percentages of HL responses:

20%:	80%:	80%-20%: Time of uncertainty	Stimulus
1.6 ST	2.8 ST	1.2 ST	laθ
2.2 ST	3.3 ST	1.1 ST	maːr
1.9 ST	3.4 ST	1.5 ST	waːr
		laθ/maːr/waːr	
1.9 ST	3.1 ST	1.2 ST	mean
0.3 ST	0.3 ST	0.2 ST	standard deviation

Table 4.9: Perceptual threshold of tone height: The number of semitones it took for participants to shift from a 20% response to an 80% response of HL identification. Up to 20%, the stimuli are mostly identified as L-toned, and above 80%, the stimuli are mostly perceived as HL.

4.4.2 Summary and discussion

Based on the production of f_0, Midpoint is a better predictor than Slope in Nuer. Therefore, it would have been a plausible outcome that Nuer listeners have problems with distinguishing HL tones from L tones because they do not differ greatly in slope, and they have a smaller contrast in midpoint compared to L vs. H tones. Recall the study by Mok and Wong (2010a) showing that Cantonese speakers have problems discriminating between the two rising tones T2 and T5, which only differ minimally in f_0. For Nuer, listeners have no difficulties in discriminating between HL and L tones regardless of the similarity of these tones. The results of the polynomial regression model showed that f_0 Height significantly affected the responses of HL or L tones. The results of the psychometric curve gave a sigmoid curve which indicates that Nuer listeners have a clear-cut perception of these tones. The time of uncertainty showed that the difference between a HL and a L tone is only 1.2 semitones in Nuer. This indicates that 1.2 semitones matters for speech communication in Nuer, differing from the study on Dutch by 't Hart et al. (1990), who claims that 3 semitones are necessary to perceive a tone difference in speech.

While level tones do not have a reference value of f_0 mainly because of register differences among speakers, contour tones do have this. A study by Tumtavitikul (1995) shows that in Thai, the main difference between contour tones and level tones lies in the interval size. A threshold of +\– 3 semitones applies to level tones while a threshold of 3–8 semitones applies to contour tones. For Nuer, the results indicate that L tones pronounced in isolation can have a fall up to 2.2 ST. Above 2.8 ST, listeners start to hear HL tones. Between these values, there is ambiguity between a HL and a L tone. This confirms the results in the production study of the previous chapter where final lowering was found in sentence-final position. L tones can in fact have a falling contour up to 2.2 ST and still be perceived as L tones.

The main differences between the items were non-significant in the polynomial model, only for specific knots. Concerning the time of uncertainty, it was the item *waːr* which stood out by needing more f_0 contrast in order to shift responses: 1.5 ST. Perhaps the most obvious differences between the items which could explain this outcome concerning the segmental differences of the onsets. The item *waːr* has a semivowel for onset and the boundary with the nucleus is gradual rather than abrupt. In comparison, the other two items with nasal and liquid onsets have more clear-cut boundaries with the nuclei. These segmental differences might have influenced the responses making the time of uncertainty longer for *waːr* compared to the other two items.

Another possible explanation for the small differences between the items relates to the (lack of) context and lexical frequency. The stimuli in the experiment were nouns pronounced in isolation without any context. It is a well-known fact that listeners of a tone language rely on contextual cues for identifying the tonal space of a speaker (Francis et al., 2006; Wong and Diehl, 2003). It might have been the case that the meanings of *waːr* ('kind of grass' sheep or goat dung') were less easy to identify compared to the other nouns when pronounced in isolation. One related reason for this might be that these nouns differ in lexical frequency in Nuer. That is, the meaning of *waːr* occur less frequently in Nuer compared with the other two nouns.

4.5 Conclusion

This chapter presented the results of two perception experiments. One on the f_0 alignment and one on f_0 height. The results indicate that Nuer listeners have a clear-cut perception of tone. f_0 alignment and f_0 height are both cues which the listeners rely on to distinguish between a HL tone and a L tone. For the former, the results show that HL tones are aligned late in Nuer, and there is a crucial point in the onset where the peak must be aligned in order for HL tones to be perceived when they follow a H target. At least 80% of the fall must be located in the vowel to obtain a HL perception. In these cases, the fall happens in an area with spectral change, at the boundary between sonorous onsets (/m,w,l/) and the nucleus (/a/). Thus, Nuer listeners can detect falling contours across the boundary of a sonorant onset and a vowel. Based on this result, I claim that the optimal tone perception hypothesis by House (1990) should be extended so that it includes sonorant onsets as domains where tonal movement can be perceived.

Nuer listeners are highly sensitive to alignment differences, and for one item, as little as 16 ms of difference was sufficient to change a L tone perception to a HL perception. For the long-vowel items, it takes longer for listeners to detect a tone change. On average, 23 ms are needed for the items tested. The slope of the fall might explain the differences between the items. Under higher time-pressure (short vowels), a change in alignment is perceptually more salient compared to the same alignment change under lower time-pressure (long vowels). The results stand out compared to other studies where 50 ms are generally needed for a shift between two tonal targets (House, 2004).

For the f_0 height experiment, an observation from the production study was confirmed. Namely that L tones can have a falling contour in utterance-final position but are still perceived as L. The results indicate the following threshold which distinguishes a HL from a L tone in Nuer: L tones can be flat (0 ST) or have a fall up to 2.2 ST. HL tones are perceived when the fall exceeds 2.8 ST. The time of uncertainty was on average 1.2 ST. There are not many studies to compare this result with, however it is lower compared to the results reported by 't Hart et al. (1990), namely, that 3 ST are necessary for listeners to perceive a tonal difference in speech communication.

The two experiments are different in that the f_0 height stimuli contained nouns pronounced without any context. As mentioned in section 4.4, Francis et al. (2006) and Wong and Diehl (2003) have shown how listeners of a tone language rely on contextual cues for identifying the tonal space of a speaker. It is an interesting result that categorical perception was obtained in the pitch height experiment with only the H reference point of the HL tone (upper scale of semitone manipulations) or without any reference points (lower scale of manipulations). A brief survey from the participants confirms that the majority reported a higher degree of difficulty for the experiment with stimuli presented in isolation compared to the experiment on alignment which had stimuli in a carrier sentence.

In sum, both experiments of this chapter indicate that Nuer listeners have a clear-cut perception of tone and that listeners are sensitive to fine-grained differences in tonal cues. The results are especially interesting considering that Nuer speakers are not aware of speaking a tone language. On the one hand, this might not be expected because there are more near-minimal pairs where tone is accompanied by alternations in, e.g., vowel quality, voice quality, or duration compared to pure tonal minimal pairs. On the other hand, the results of the experiment support the main contribution of this dissertation. Namely that tone plays a prominent role in Nuer. In fact, Nuer listeners have abilities to perceive fine-grained changes in tonal cues.

Part II

Tonotactics

Chapter 5

OCP-L in the nominative case

The most prominent aspect of Nuer tonotactics is the restriction on adjacent L tones. This part of the dissertation focuses on the phonological aspects of tone and the ways adjacent L tones are repaired in the nominative case. I will show that this type of Nuer tonotactics provides independent evidence of underlying tones. The arguments presented here will be fundamental for the analysis of nominal inflection in the next part of this dissertation on grammatical tone.

The ban on adjacent L tones observed in this study plays out in many different ways. When underlying L-toned syllables co-occur, they surface with a tonal polarity pattern. This polarity pattern is found on stems and suffixes at the lexical and post-lexical level. I argue that the polar patterns arise due to a ban on adjacent L level tones in Nuer known as the Obligatory Contour Principle (OCP). This is a well-established phenomenon observed in many languages. Cross-linguistically for tonal languages, the OCP is most often active for H tones. Nuer is therefore typologically unusual in displaying OCP-L (68).

(68) OCP-L
Adjacent L level tones are banned (*L L).

When syllables are underlying L-toned in the input, the output is repaired by H tone epenthesis which is a floating tone, i.e., without a root node. This is inserted in a suffix position (69).

(69) High tone epenthesis
A floating H tone is inserted in a suffix position when L tones are adjacent in the input.

The interesting point about H tone epenthesis is that it works as a diagnosis for underlying tonal specification. First, I argue that H tone epenthesis targets different syllables depending on their tonal specification. This is explained by assuming defective tonal structures where some syllables are entirely toneless, some have a floating tone or tonal tree in the input, and some syllables have a lexically linked tone – see also section 1.5 for an overview. Second, according to Pulleyblank (1986) and many following scholars, floating L tones induce downstep. Nuer nouns which have a floating tone in the input are called 'unstable nouns'. As shown in section 5.1, when H tone epenthesis targets their stem in the nominative case, they surface with a downstepped H tone induced by their lexical floating L tone.

Section 5.2 presents stable tone patterns. Stable nouns have a L tone linked to the stem syllable in the input. When they are the possessor noun, H tone epenthesis cannot target these syllables, and the H tone goes on an adjacent target if this is possible. Section 5.3 shows that the infrequent nouns with a lexical M tone, which were presented in section 2.2, do not change with adjacent L tones. Section 5.4 compares stable and unstable nouns in the same contexts.

A final phonological property which the OCP-L reveals is the structure of HL tones. While L tones violate OCP-L, H and HL tones do not. Therefore, I claim that HL tones have a unitary structure which does not violate the OCP-L when it precedes or follow L tones. The autosegmental structures of HL tones and the autosegmental processes of H tone epenthesis in the nominative case are shown in section 5.5. Section 5.6 summarizes the chapter.

5.1 Unstable tone patterns

The nouns presented in this section are called 'unstable' because they change their tone in various contexts. Besides changing their stem tone in inflection – see chapters 7 and 9, unstable nouns which are L-toned change to a downstepped H tone in contexts with adjacent L tones. One example of this is when a L-toned noun follows an auxiliary which also has a L tone. If it were stable, it would stay L in this position, as shown below in sections 5.2 and 5.4. The changes on unstable nouns are illustrated below. The noun *lòɲ* has a L tone and remains L when following the H-toned first-person auxiliary *c-ḛ̤́* (70a) or the H-toned imperative verb (70b).

(70) Lexical L tone after H

a. hḛ̤̄n c-ḛ̤́ lòɲ nɛ̂·n
1SG PFV-1SG lion see
'I see the lion.'

b. nɛ́·n lòɲ
see.IMP.SG lion
'Look at the lion!'

In comparison, when this noun follows the L-toned third person auxiliary *c-ɛ̀*, H tone epenthesis targets *lòɲ* (71). Note that the verbal stem *nɛ·n* 'see' has a L tone – see e.g. (82) – and gets a HL tone in L tone sequences. The tone structure of this verb will be discussed in section 5.5.

(71) c-ɛ̀ ꜜlóɲ nɛ̂·n
PFV-3SG lion see
'(S)he has seen the lion.'

The fact that *lɔ̀ɲ* in (71) surfaces with a downstepped H tone can be explained by the fact that the H tone from H tone epenthesis is lowered by the lexical L tone which I assume is floating in the input: /ᴸlɔɲ/. When the H tone links to the noun, this L tone creates a downstep. Additionally, this floating tone also lowers the HL tone of *nɛ̂ˑn* – see chapter 6 for the phonetics of this process. These mechanisms are further explained in section 5.5 which outlines the autosegmental structures of H tone epenthesis.

Examples of this pattern can be observed for other unstable L-toned nouns below in (73), which also get a downstepped H tone. Each of these examples display a L tone when following a H tone (72).

(72) **L tone nouns**

a. nɛ́ˑn ɲàˑl
see.IMP.SG girl
'Look at the girl.'

b. nɛ́ˑn wàŋ
see.IMP.SG eye
'Look at the eye.'

c. nɛ́ˑn màːr
see.IMP.SG blood.relationship
'Look at the blood relationship.'

(73) **H tone epenthess on L tone nouns**

a. c-ɛ̀ ꜜɲáˑl nɛ̂ˑn
PFV-3SG girl see
'(S)he has seen the girl.'

b. c-ɛ̀ ꜜwáŋ nɛ̂ˑn
PFV-3SG eye see
'(S)he has seen the eye.'

c. c-ɛ̀ ꜜmáːr nɛ̂ˑn
PFV-3SG relationship see
'(S)he has seen the relationship.'

The same phenomenon can be observed in sequence-initial position. L-toned unstable nouns such as *lɔ̀ɲ* 'lion' also surface with a downstepped H tone when they precede the L-toned predicate *gwà-ɛ̀ː* (74).

(74) /ᴸlɔɲ gwà-ɛ̀ː/
ꜜlɔ́ɲ gwà-ɛ̀ː
lion good-3SG
'The lion is good.'

Another context where unstable nouns get H tone epenthesis is when they follow the first-person singular index, which is L-toned: -ɐ̤̀. In the carrier sentence *lâˑr-ɐ̤̀ X kákɛ̂l* 'I say X once', the unstable L-toned noun *lɔ̀ɲ* gets a downstepped H tone because it is adjacent to the L-final suffix -ɐ̤̀ (75).[1]

(75) OCP-L repair on noun
hɐ̤̄n lâˑr-ɐ̤̀ ꜜlɔ́ɲ kákɛ̂l
1SG say-1SG lion once
'I say lion once.'

[1] The M tone on the personal pronoun is considered lexical, possibly composed by a a linked tone and a floating tone. It is transcribed as a M as a convention since it always has this tone. Phonetically, it is on the same level as the downstepped H tone.

In comparison, no downstep appears on the H and HL tones of *tét* and *dɛ̂ˑl* below in (76) since these contexts do not produce OCP-L violations.

(76) No OCP-L violations

a. hē̤n lâˑr-è̤ tét kákɛ̂l
1SG say-1SG hand once
'I say hand once.'

b. hē̤n lâˑr-è̤ dɛ̂ˑl kákɛ̂l
1SG say-1SG sheep once
'I say sheep once.'

5.2 Stable tone patterns

Some nouns have a stable tone pattern by being immune to H tone epenthesis and staying L-toned in positions where unstable L-toned nouns would undergo H tone epenthesis. Violations of the OCP-L in these contexts are repaired by epenthesizing a H tone to adjacent L tone targets. In chapter 7, these nouns will be referred to as either 'stable' or 'hybrid' because they retain their tone in OCP-L violations and also in inflection, but hybrid nouns behave differently in the oblique case. In this chapter, they are both characterized as 'stable'.[2] The tonal structure of hybrid and stable nouns is identical at the phrase level in the nominative because they both have a linked tone at this level, and consequently, they behave identical in OCP-L violations.

Recall the example in (75) above where *lɔ̀ɲ* 'lion' got a downstepped H tone after the first-person singular index -è̤. In contrast, the stable L-toned nouns in (77) remain L-toned in this context. Observe that a rising tone appears on the verbal suffix. This rising tone on *lâˑr-ě̤* only surfaces when a L-toned noun follows. After H- and HL-toned nouns, it was shown that it is L-toned; see (76). The rising tone in *lâˑr-ě̤* is considered here an allotonic realization of H tone epenthesis, as M tones have. The context of this variation is not entirely clear since they are not positioned sentence-initially.

OCP-L repair on verbal suffix

(77) a. hē̤n lâˑr-ě̤ kè̤ːr kákɛ̂l
1SG say-1SG line once
'I say line once.'

b. hē̤n lâˑr-ě̤ cɔ̤̀a̤ː
1SG say-1SG bone
kákɛ̂l
once
'I say bone once.'

c. hē̤n lâˑr-ě̤ tò̤t
1SG say-1SG summer
kákɛ̂l
once
'I say summer once.'

Evidence that the stable L-toned nouns have a lexical L tone is that they appear as L in other contexts, e.g., after the H-toned auxiliary in (78). They are also L-toned when they precede the L-toned predicate (79).

[2] Two nouns shown in this chapter; *cɔ̤̀a̤ː* 'bone' and *lè̤k* 'dream' are hybrid nouns, and the rest are stable nouns.

(78) L tones after H

a. hē̤n c-é̤ kè̤ːr nɛ̂ˑn
1SG PFV-1SG line see
'I have seen the line.'

b. hē̤n c-é̤ cɔ̤̀a̤ː nɛ̂ˑn
1SG PFV-1SG bone see
'I have seen the bone.'

c. hē̤n c-é̤ tò̤t nɛ̂ˑn
1SG PFV-1SG summer see
'I have seen the summer.'

(79) L#L sequence

a. kè̤ːr gwà-ɛ̀ː
line good-3SG
'The line is good.'

b. cɔ̤̀a̤ː gwà-ɛ̀ː
bone good-3SG
'The bone is good.'

c. tò̤t gwà-ɛ̀ː
summer good-3SG
'The summer is good.'

The examples in (79) with the L-toned predicate show a rare L#L sequence in Nuer without any OCP-L repair. Remember that in this context, the unstable L-toned noun *lɔ̀ɲ* 'lion' got H tone epenthesis as in (74) above. This indicates that there are restrictions concerning the targets which can be repaired in OCP-L violations. First, in the contexts showed here, H tone epenthesis only targets unstable nouns. Second, stable L-toned nouns remain L while the tones of the preceding element can be raised, e,g., the auxiliary and the verbal suffix. At the same time the verb stem *nɛ̀ˑn* 'see' can get a HL tone as in (78) above. But not all items which follow the nouns get H tone epenthesis, and it seems impossible to repair OCP-L by raising the tone of the predicate as in (79). These differences indicate that not only the kind of nouns matter (stable vs. unstable) in OCP-L violations but also the position of the L-toned syllables.

5.3 Lexical M tones

Nouns with a lexical M tone do not change as a reflex of on the surrounding tones. This indicates that they are insensitive to the OCP-L and behave like nouns with a H or HL tone in this aspect. As was already mentioned in chapter 2, they are M-toned before and after other L tones. The former is shown in (80) – repeated from (44). Recall also that these M-toned nouns have a rising allotone in sentence-initial position, e.g., *twɔ̤̌ˑt* in (80b).

(80) Lexical M tones

a. cɔ̤̄ˑw gɔ̀ˑw-kɛ́
bone\PL good-3PL
'The bones are good.'

b. twɔ̤̌ˑt gwà-ɛ̀ː
wild.goose good-3SG
'The wild goose is good.'

As expected, the lexical M tones are also M-toned following the L-toned person index in (81). In this context, they are phonetically on the same f_0 level as the raised L tones in, e.g., (75) above.

As mentioned in section 2.2, these nouns are transcribed with a M (or low-high). Underlyingly, I assume they have two lexical tones; a linked tone and floating tone which together create this surface M tone – see section 10.2.2 for a discussion of this.

(81) Lexical M tones

a. hē̤n lâ·r-ὲ̤ cɔ̤̄·w kákε̂l
1SG say-1SG bone\PL once
'I say bones once.'

b. hē̤n lâ·r-ὲ̤ twɔ̤̄·t kákε̂l
1SG say-1SG wild.goose\PL once
'I say wild goose once.'

5.4 Differences between stable and unstable nouns

This section looks at OCP-L violations with nouns following an auxiliary and preceding a verb stem. The third person singular auxiliary in the perfective has a L tone – *c-ὲ*, and when it precedes a L-toned noun, sequences of three L tones can arise in sentences, e.g., with the sequence; auxiliary – object – verb. Verb stems such as *nὲ·n* 'see' are underlyingly L. Evidence of this comes from the L tone it has when it follows a H or HL noun, as in (82). The imperative form of the same verb has a H tone in front of HL and L tones, but a M tone preceding H tones – see chapter 3. The lexical tones of the nouns can be verified when they follow this verb form in (83).

(82) H or HL-toned nouns: no sandhi

a. c-ὲ jâŋ nὲ·n
PFV-3SG cow see
'(S)he have seen the cow.'

b. c-ὲ ně̤ːr nὲ·n
PFV-3SG uncle see
'(S)he have seen the uncle.'

(83) Sentence showing lexical tone

a. nέ·n jâŋ
see.IMP.SG cow
'Look at the cow!'

b. nε̄·n ně̤ːr
see.IMP.SG uncle
'Look at the uncle!'

The vowel of the third person singular auxiliary *c-ὲ* gets lengthened and undergoes H tone epenthesis when it precedes stable L-toned nouns as in (84). This form can be compared to the examples in (85) where the auxiliary has a L tone and the unstable L-toned are subject to H tone epenthesis. The superscripted L in the underlying structure (/^{L}/) represents the stem with a floating L tone. In these examples, note also the tone of the verb *nὲ·n*. While it was L-toned after the H- and HL-toned nouns in (82), it gets a HL tone after the unstable (85) and stable (84) L-toned nouns: *nε̂·n*. Because the HL tone appears after a L tone in (84), it seems to be an OCP-L repair.

(84) Stable L nouns

a. /c-ɛ̀ kè̤ːr nɛ̀ˑn/
ꜜc-ɛ́ˑ kè̤ːr nɛ̂ˑn
PFV-3SG line see
'(S)he has seen the line.'

b. /c-ɛ̀ tɔ̤̀t nɛ̀ˑn/
ꜜc-ɛ́ˑ tɔ̤̀t nɛ̂ˑn
PFV-3SG summer see
'(S)he has seen the summer.'

(85) Unstable L tones

a. /c-ɛ̀ ᴸmaːr nɛ̀ˑn/
c-ɛ̀ ꜜmáːr nɛ̂ˑn
PFV-3SG relationship see
'(S)he has seen the relationship.'

b. /c-ɛ̀ ᴸwaŋ nɛ̀ˑn/
c-ɛ̀ ꜜwáŋ nɛ̂ˑn
PFV-3SG eye see
'(S)he has seen the eye.'

It is puzzling that the HL tone on the verbal stem also appears after the epenthesized H tone on unstable L tones in (85) because the tones of these nouns have already been raised, and such sequences are not expected to violate the OCP-L if the verb would stay L. I claim that the HL tone on the verb in (84) and (85) are due to two separate processes. When it follows a L-toned target as in (84), H tone epenthesis applies on the verb itself, creating the HL tone. When it follows an unstable L-toned noun which undergoes H tone epenthesis, the H tone inserted on the noun spreads onto the verb as well, creating the HL tone. As I propose in section 5.5, the verb has an autosegmental structure which allows for a derived HL tone.

Until now, only three-syllable sentences have been examined. The question is what kind of OCP-L repair is expected when a fourth syllable is added in the L-toned sentences. The data below show sentences with the possessive suffixes for stable and unstable nouns. It will be shown in section 7.5.1 and 10.2.3 that the possessive markers have an underlying tone and do not alter it, regardless of OCP-L violations. This is true also at the post-lexical level.

Consider the examples below. In (86a), the L-toned noun remains L while H tone epenthesis targets the verb. When the H-toned possessive marker of first-person singular (*-dɛ̤́*) is added to the stem, no H tone epenthesis applies to the verb (86b). This is expected because the H-toned suffix breaks up adjacent L tones between the nouns and the verbal stem.

H tone epenthesis does, however, apply on unstable nouns. The same constructions can be observed in (87). Following the L-toned auxiliary, stems of unstable nouns are subject to H tone epenthesis as expected (87a) – repeated from (71). When the H-toned possessive marker is added, H epenthesis also applies on the unstable noun while the auxiliary and verb stem remain L-toned (87b). This latter example is important because it shows that L#L sequences are not tolerated between the auxiliary and the noun. The tone raising of unstable nouns from *lɔ̀ɲ* to ꜜ*lɔ́ɲ* in (87a) must, therefore, be due to both the L tones of the verb and auxiliary.

When the L-toned possessive marker *-dɛ̀* (3SG) is added to the stems, the noun with the stable tone pattern again remains L, and H tone epenthesis targets instead the verb stem and the auxiliary (86c). In contrast, the unstable noun and the verb get H tone epenthesis, while the possessive marker and auxiliary remain L-toned (87c).

(86) **Stable pattern**
/c-ɛ̀ cɔ̤̀a̤ː nɛ̀ˑn/

a. ↓c-ɛ́ˑ cɔ̤̀a̤ː nɛ̂ˑn
PFV-3SG bone see
'(S)he has seen the bone'

b. ↓c-ɛ́ˑ cɔ̤̀a̤ː-dɛ̤́ nɛ̀ˑn
PFV-3SG bone-POSS.1SG see
'(S)he has seen my bone'

c. ↓c-ɛ́ˑ cɔ̤̀a̤ː-dɛ̀ nɛ̂ˑn
PFV-3SG bone-POSS.3SG see
'(S)he has seen her/his bone'

(87) **Unstable pattern**
/c-ɛ̀ ^{L}loɲ nɛ̀ˑn/

a. c-ɛ̀ ↓lóɲ nɛ̂ˑn
PFV-3SG lion see
'(S)he has seen the lion.'

b. c-ɛ̀ ↓lóɲ-dɛ̤́ nɛ̀ˑn
PFV-3SG lion-POSS.1SG see
'(S)he has seen my lion.'

c. c-ɛ̀ ↓lóɲ-dɛ̀ nɛ̂ˑn
PFV-3SG lion-POSS.3SG see
'(S)he has seen her/his lion.'

The exact same patterns can be observed for the noun *lɛ̤̀k* 'dream' in (88) which behaves stable, and for the unstable noun *ɲàl* 'girl' in (89).

Stable pattern: H tone only on verb

(88) /c-ɛ̀ lɛ̤̀k nɛ̀ˑn/

a. ↓c-ɛ́ˑ lɛ̤̀k nɛ̂ˑn
PFV-3SG dream see
'(S)he has seen the dream.'

b. ↓c-ɛ́ˑ lɛ̤̀k-dɛ̤́ nɛ̀ˑn
PFV-3SG dream-POSS.1SG see
'(S)he has seen my dream.'

c. ↓c-ɛ́ˑ lɛ̤̀k-dɛ̀ nɛ̂ˑn
PFV-3SG dream-POSS.1SG see
'(S)he has seen her/his dream.'

Unstable pattern: H tone on object + verb

(89) /c-ɛ̀ ^{L}ɲal nɛ̀ˑn/

a. c-ɛ̀ ↓ɲáˑl nɛ̂ˑn
PFV-3SG girl see
'(S)he has seen the girl.'

b. c-ɛ̀ ↓ɲáˑl-dɛ̤́ nɛ̀ˑn
PFV-3SG girl-POSS.1SG see
'(S)he has seen my girl.'

c. c-ɛ̀ ↓ɲáˑl-dɛ̀ nɛ̂ˑn
PFV-3SG girl-POSS.3SG see
'(S)he has seen her/his girl.'

The data indicate that when the H-toned possessive marker *-dɛ̤́* (1SG) attaches to the stem, no OCP-L violation occurs, and therefore, no H tone epenthesis applies. The odd thing is that when the L-toned possessive marker *-dɛ̀* (3SG) attaches to the stem, the minimal repair for OCP-L would be to raise it to H so that /L#L-L#L/ is repaired to either [↓H#L-↓H#L] or [L# ↓H-L#HL]. We would then expect patterns like (90) and (91) where the L-toned possessive marker has a surface H tone. This does not happen, and such sentences are ungrammatical.

Unattested data

(90) /c-ɛ̀ cɔ̤̀a̤ː-dɛ̀ nɛ̀ˑn/
*↓c-ɛ́ cɔ̤̀a̤ː-↓dɛ́ nɛ̀ˑn
PFV-3SG bone-POSS.3SG see
'(S)he has seen her/his bone.'

(91) /c-ɛ̀ ^{L}loɲ-dɛ̀ nɛ̀ˑn/
*↓cɛ́ lòɲ-↓dɛ́ nɛ̀ˑn
PFV-3SG lion-POSS.3SG see
'(S)he has seen her/his lion.'

It is possible that the $^{\downarrow}$H tone on the auxiliary observed in (86) and (88) is caused by a separate grammatical process independent of the OCP-L. The third person auxiliary is L-toned as expected when it follows a HL-toned noun as *yâŋ* 'cow' in (92a). Interestingly, when *yâŋ* is used as a name of a person, the auxiliary undergoes a tone raising and vowel lengthening. Thus, this happens even without adjacent L tones. This alternation is found with many nouns. Another example is *pâl* which either means 'prayer' (92b) or the name *Pâl* (93b). The common property for the nouns which trigger the long H-toned vowel on the auxiliary is that they are stable nouns, while nouns which do not trigger this auxiliary form are unstable nouns – see chapter 7, for criteria for stable and unstable besides H tone epenthesis, and appendix A for an overview. Thus, when unstable nouns follow the auxiliary as *dîˑt* in (92c), the auxiliary is L-toned and short. When a stable noun such as *gwàk* 'fox', which generally does not undergo H tone epenthesis, follows the auxiliary, the long H-toned form appears again on *c-ὲ* (93c).

Differential Object Marking

(92) *Unstable nouns*

a. c-ὲ yâŋ nὲˑn
PFV-3SG cow see
'(S)he has seen the cow.'

b. c-ὲ pâl nὲˑn
PFV-3SG prayer see
'(S)he has seen the prayer.'

c. c-ὲ dîˑt nὲˑn
PFV-3SG bird see
'(S)he has seen the bird.'

(93) *Stable nouns*

a. ↓c-έˑ Yâˑŋ nὲˑn
PFV-3SG Yang see
'(S)he has seen Yang.'

b. ↓c-έˑ Pâˑl nὲˑn
PFV-3SG Pal see
'(S)he has seen Pal.'

c. ↓c-έˑ gwàk nɛ̂ˑn
PFV-3SG fox see
'(S)he has seen the fox.'

The pattern observed in (93) might a phenomenon called Differential Object Marking (DOM) (Bossong, 1991; Aissen, 2003).[3] DOM involves case marking of certain types of direct objects which share a semantic or grammatic feature. Objects which do not have such features may be unmarked for case. It is common that such features regard animacy or definiteness. For example, in Romanian, object case marking is obligatory for proper nouns and for personal pronouns referring to animate features (Farkas, 1978).

For Nuer, the special form of the auxiliary also appears with pronouns. This indicates that the grammar is sensitive to definiteness. It is notable that stable nouns such as *gwàk* in (93c) also trigger the special form on the auxiliary. I argue that this indicates that the grammar in Nuer is sensitive to the stable – unstable noun distinction which I propose here. To foreshadow chapter 7, this distinction in nouns is also motivated by the suffixation patterns in case and number marking.

[3] Note that Faust and Grossman (2015) discuss DOM with another type of data in Nuer. They observe that Nuer has DOM because verbs alternate their form depending on whether they encode an oblique-flagged postverbal object or an unflagged preverbal one. In the Western Nilotic literature, this is referred to as transitive vs. antipassive forms.

According to Reid (p.c), the pattern observed in (93) might be due to a suprasegmental prefix consisting of a floating mora and a H tone which belongs to the nouns triggering this auxiliary form. This prefix manifests itself on the preceding word such as the auxiliary. Even if the raised tone on the auxiliary *cɛ̀* is triggered by independent processes in the grammar, I claim the tone raising on this auxiliary and on unstable nouns can be phonologically derived by H tone epenthesis. That is, unstable L-toned nouns get H tone epenthesis in front of the L-toned auxiliary *cɛ̀* regardless of the following tones – see (87) and (89) above. In these contexts, I propose that H tone epenthesis triggers the raised tone of unstable nouns and the auxiliary preceding stable nouns.

5.5 Autosegmental structures and H tone epenthesis

In this section, I present the autosegmental structures which can capture the differences between stable and unstable stems. These generalizations are based on the principles of autosegmental phonology by Goldsmith (1976) where tones are represented on separate tiers from segmental material and prosodic elements. The tones are connected to prosodic elements such as moras or syllables via association lines. The analysis for Nuer relies on a structural enrichment of the tonal make-up in syllables. In this approach, I employ tonal root nodes (referred to as 'root nodes') as an extra layer of structure designated to host tones. These nodes have a crucial function in the analysis because they can capture different levels of defectiveness which has been empirically observed in this chapter. They can also capture the structure of HL tones.

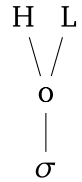
5.5.1 HL tones

The root nodes I adopt for Nuer is a simplified version of structures used in register theory (cf. Hyman, 1993; Pulleyblank, 1986; Yip, 1990, 1995; Snider, 1999). Yip uses root nodes for different purposes. In Yip (1990, 1995), the aim is to capture tone systems in East Asian languages with registers, e.g., the upper and lower register of a rising tone. In the version I adopt from Yip (1989), the main function of root nodes is to capture differences between contour tones. Since lexical contour tones in Nuer do not differ in register, I omit this layer of representation – see also section 10.2.

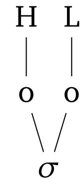
Contour tones have typological differences indicating that in some languages they are a unit, while in other languages they are clusters of level tones. Yip (1989) proposes two different structures for contour tones: The 'unitary' structure (also referred to as 'branching') has a TBU consisting of one root node hosting two level tones (94). It contrasts with cluster tones which involves a TBU with two root nodes which each hosts a level tone (95).

Two distinct structures for contour tones (Yip, 1990)

Unitary contour tone

(94) 

Cluster contour tone

(95) 

The autosegmental structure used for Nuer is organized hierarchically; the different tiers in (94) and (95) show the syllable (σ), the root node (o), and the tones (H, L). I represent tones as two atomic units (H or L).

For Nuer, I adopt the unitary structure in (94) for lexical HL tones in Nuer. This structure makes predictions on the typological status of contour tones in Nuer. For example, as Yip (1989) notes, contour tones in Bantu languages differ greatly compared to contour tones in East Asian languages. In Bantu, contour tones are often restricted to the final syllable of a domain and arise through tone spreading, or they appear as a result of a floating tone attaching to a syllable with an existing tone, e.g., in contexts with vowel deletion. These cases indicate that the contour tones result from a concatenation of two level tones and are compatible with the structure in (95). In other words, they are derived contour tones. This explains why their distribution is restricted to tonal processes, e.g., tone spreading or tone linking due to vowel deletion.

Contour tones in Bantu languages contrast with contour tones in East Asian languages in that they are commonly unrestricted regarding their distribution. This indicates that they form a constituent and are *not* a concatenation of level tones. These properties are compatible with a unitary structure as in (94) above. More evidence of unitary structures of contour tones involves spreading or assimilation. For example, in Danyang, contour tones spread as a unit onto adjacent syllables (Chen, 1996; Yip, 1989). Other evidence is given by Chen (2000: 77) for Wenzhou where a HM tone is shifted across an arbitrary sequence of toneless syllables to the word-initial position. In other words, the whole contour tone shifts as a unit. Another argument regards the OCP which has shown not only to be sensitive to adjacent level tones which are identical but also to adjacent contour tones which are identical. For example in Tianjin (Yip, 1989), sequences of identical contour tones are subject to simplification.

Generally in Western Nilotic languages, tone behaves more similarly to East Asian tone languages than to tone in Bantu languages. For example, Nuers related language, Shilluk, has five contour tones which are phonologically contrastive and appear freely on monosyllabic stems. Nuer has lexical HL tones whose distribution is unrestricted, opposing on short, mid and long vowels – see chapter 2. For this reason, I argue that they are lexically underlying contour tones. Under this view, Nuer is more similar to East Asian languages in that contour tones display few to no positional restrictions, not limited only to final syllables or surfacing as a result of segmental processes such as vowel deletion. By adopting root nodes in Nuer, it is possible to distinguish between lexical HL tones, which behave as a unit, and derived contour tones, which behave as a sequence of two tones.

If one follows Yip (1989) in assuming that contour tones differ typologically by having a cluster structure, as in many Bantu languages, or a unitary structure, as in many East Asian languages, it seems clear that lexical HL tones in Nuer have properties more similar to East Asian contour tones than to Bantu contour tones. Unlike lexical HL tones, derived HL tones are very rare in Nuer and only found in sentence-final positions, e.g., on the verbal stem *nɛ̂·n*.

Besides the unrestricted distribution of the unitary HL tones, the OCP-L constraint indicates that contour tones on nouns are *not* a cluster of level tones. If the HL tones observed on nouns were really composed of a H and a L level tone, it would be expected that the L component of the contour tone would trigger the same tonal processes as a L level tone. As was seen in e.g., (76b), this is not the case. Therefore, I argue that the HL tones found on nouns are lexical and have a structure which does not induce OCP-L violations when L tones precede or follow them.

The fact that HL tones do not trigger OCP-L violations makes sense under the assumption that they are a unit branching from a single root node. This is represented in (96). This contrasts with a contour tone which is a cluster of two level tones each hosted by a root node. Such contour tones are predicted to violate OCP-L (97). The same goes for two adjacent level tones which also violate this constraint (98).

(96) No OCP-L violation

```
H L  L
 \/  |
 o   o
 |   ¦
 σ  -σ
```

(97) OCP-L violation

```
*H L  L
 |  |  |
 o  o  o
  \/   ¦
  σ   -σ
```

(98) OCP-L violation

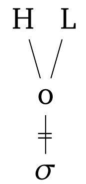
```
*L  L
 |  |
 o  o
 |  ¦
 σ -σ
```

5.5.2 Autosegmental operations

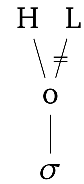
Common autosegmental operations are spreading and deletion. If the association line between a tone and a syllable is deleted, it will not be pronounced on the surface. The unitary structure with one root node makes predictions for how tonal spreading and deletion works. These mechanisms are given below. The root node allows for deletion between the syllable and the root node as in (99). Here, the whole contour tone is deleted and remains floating as a unit together with the root node (a floating HL tonal tree).

In addition to the lower association line deletion, I assume that deletion is possible between the root node and the tone itself as in (100). In this example, it turns a HL-toned syllable into a H-toned syllable. The unitary contour tone spreads by associating the tonal node to another syllable, i.e., a whole unitary contour tone can spread (101) just as it can float as a unit in (99).

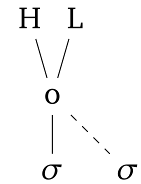
(99) Lower deletion



(100) Upper deletion

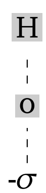


(101) Spreading



The dashed line in (101) above marks tone spreading. This dashed form indicates that the association line was not in the input but has been inserted in the output. Similarly, if a root node, a syllable, or a tone is inserted in an output, these elements are marked in a gray box. This is illustrated in (102) below where everything except the syllable is inserted: the H tone, the root node, and the dashed association lines between the tone and the root node, and between the root node and the syllable. Note that the hyphen preceding the syllable (-σ) represents a suffix.

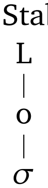
(102) Epenthetic material



5.5.3 Structure of stems and H tone epenthesis

The two types of nouns which were introduced in this chapter – stable and unstable – must contrast structurally from each other since they behave differently in relation to H tone epenthesis. Their distinctions can be captured with root nodes. Both kinds of nouns can have a lexical H, L, or HL tone. The difference between them lies in their autosegmental structure. The stable nouns are fully specified with a linked tone on the stem syllable (103). Unstable nouns, on the other hand, have a floating lexical tone in the input and are defective because they lack a root node (104).

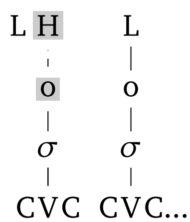
(103) Stable noun



(104) Unstable noun

The H tone from H tone epenthesis can link to unstable stems without violating any faithfulness constraints because the stems are not linked to their lexical tones in the input. The same goes for grammatical tones which also link freely to unstable stems, as will be shown in chapter 7. In order for H tone epenthesis to apply, a root node needs to be inserted for unstable nouns. The phonetic realization of H tone epenthesis is a downstepped H tone because the lexical floating L tone in /^{L}loɲ/ lowers the inserted H tone. This is represented below in (105). An example of this would be (106), repeated from (74) above.

H tone epenthesis on unstable L nouns

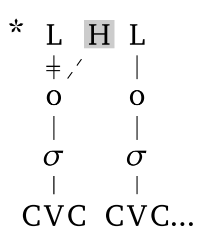
(105) 

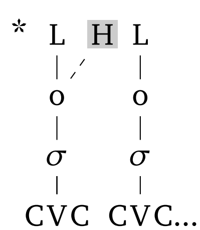
(106) /^{L}loɲ gwà-ɛ̀ː/
$^{\downarrow}$lóɲ gwà-ɛ̀ː
lion good-3SG
'The lion is good.'

Thus, evidence of these lexical floating L tones comes from the downsteps they induce on H tones. The stems of unstable nouns are not completely toneless because their lexical tones show up in contexts where no OCP-L violations occur – see, e.g., (70) in section 5.1. This is possible through the insertion of a root node – see chapter 9. Note that the distinction between stable and unstable nouns in the nominative case is only revealed in contexts with OCP-L violations; i.e., when they have a lexical L tone and are adjacent to other L tones. When nouns have H or HL tones, the stable – unstable distinction is revealed in case inflection – see chapter 7.

For stable nouns, their lexical tone is linked to the stem underlyingly. When they are L-toned and appear adjacent to other L tones, it is impossible for the epenthesized H tone to overwrite their lexical tone (107), or link to the syllable creating a HL tone (108). In some cases, this can result in an OCP-L violation as in (109) – repeated from section 5.2.

Illicit structures: No H tone epenthesis on stable nouns

(107) 

(108) 

(109) /kɛ̤̀ːr gwà-ɛ̀ː/
kɛ̤̀ːr gwà-ɛ̀ː
line good-3SG
'The line is good.'

In sentences with stable nouns, the question remains why H tone epenthesis cannot target words such as the predicate *gwà-*ɛ̀ː in (109), but it can target other words such as the verbal stem and the preceding auxiliary. I assume there are two conspiring reasons for this. One reason concerns the underlying tones of the words. Syllables without a linked tone are free to get the epenthesized H tone without violating any faithfulness constraints. In cases where all tones are underlyingly L, prosodic structure comes in. I claim that tonal faithfulness of the right-most tone linked to a syllable of a p-phrase is favored over faithfulness of tones in other positions.

One cue which indicates prosodic structure in Nuer is pauses. I standardly assume that each lexical word, including affixes, forms a prosodic word (ω) – see Selkirk 1995, among others. At the level above prosodic words, I claim that a pause indicates a phonological phrase boundary. Pauses are found in some contexts, and when there is no pause, I claim a sequence forms one p-phrase. With this criterion, the auxiliary and the object form a p-phrase (ϕ): ((c-ὲ)$_\omega$ (cɔ̤̀a̤ː)$_\omega$)$_\phi$. The hypothesis is that the tone of the noun *cɔ̤̀a̤ː* is preserved because it is linked to the right-most syllable of the p-phrase. H tone epenthesis targets *c-ὲ* rather than the stable nouns for this reason. This prosodic preference is observed in different structures and will be discussed in more detail in chapter 9.

(110) /((c-ὲ)$_\omega$ (cɔ̤̀a̤ː)$_\omega$)$_\phi$ ((nὲˑn)$_\omega$)$_\phi$/
ꜜc-έˑ cɔ̤̀a̤ː nɛ̂ˑn
PFV-3SG bone see
'(S)he has seen the bone'

In the sentence with a non-verbal predicate, on the other hand, the prosodic structure differs. Speakers consistently pronounce a pause between the subject and the non-verbal predicate. This indicates that they form two separate p-phrases. The stable noun *kè̤ːr* has an underlying L tone, and *gwà-ὲː* must also have an underlying L tone since its tone remains the same regardless of the surrounding tones. Thus, both words have an underlying L tone which is linked to the right-most syllable of their own p-phrases (111). This protects both words, and no H tone epenthesis applies.[4]

(111) Prosodic structure
((kè̤ːr)$_\omega$)$_\phi$ ((gwà-ὲː)$_\omega$)$_\phi$
line good-3SG
'The line is good.'

This hypothesis predicts that if two underlying L tones are adjacent and part of the same p-phrase, the L tone linked to the right-most syllable will be preserved while the L tone linked to the left-most syllable will be subject to H tone epenthesis. In chapter 7 and 9, I show additional examples where this prediction is borne out. In addition, if there are underlying p-phrase-medial L tones, OCP-L is repaired by merging L tones. Thus, the only underlying L tones which are *not* preserved in Nuer are left-most tones in a p-phrase.

Finally, the examples with a HL tone on the verb *nɛ̂ˑn* are also a result of H tone epenthesis. However, there are a few things to notice about these derivations. I mentioned that contour tones are underlying in Nuer, and it is striking how the only derived contour tone found in this

[4]Concerning the adjacent L tones on *gwà-ὲː*, I assume they do not violate the OCP-L because the L tones are merged on this word.

study is restricted to a final syllable of an utterance. The verbal stem is underlyingly L-toned as it appears with a L tone after H and HL tones – see section 5.4. After the H-toned possessive marker *-dɛ̤́*, the verbal stem is also L-toned (112)–(113).

(112) /c-ɛ̀ˑ cɔ̤̀a̤ː-dɛ̤́ nɛ̀ˑn/
↓c-ɛ́ˑ cɔ̤̀a̤ː-dɛ̤́ nɛ̀ˑn
PFV-3SG bone-POSS.1SG see
'(S)he has seen my bone'

(113) /c-ɛ̀ ᴸloɲ-dɛ̤́ nɛ̀ˑn/
c-ɛ̀ ↓lóɲ-dɛ̤́ nɛ̀ˑn
PFV-3SG lion-POSS.1SG see
'(S)he has seen my lion.'

It is puzzling that the HL tone on the verb appears after both unstable nouns which have been subject to H tone epenthesis, as in (115a), and after L tones. That is, *nɛˑn* is HL after the unstable L tone in (114a) and the L-toned possessive marker *-dɛ̀* in (114b) and (115b). These different patterns indicate that the HL tone is not caused by two different processes.

(114) **Stable pattern**
/c-ɛ̀ cɔ̤̀a̤ː nɛ̀ˑn/
a. ↓c-ɛ́ˑ cɔ̤̀a̤ː nɛ̂ˑn
PFV-3SG bone see
'(S)he has seen the bone'
b. ↓c-ɛ́ˑ cɔ̤̀a̤ː-dɛ̀ nɛ̂ˑn
PFV-3SG bone-POSS.3SG see
'(S)he has seen her/his bone'

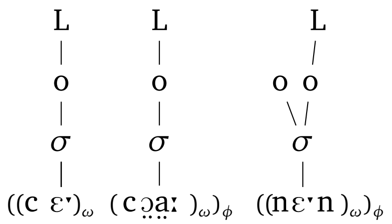
(115) **Unstable pattern**
/c-ɛ̀ lòɲ nɛ̀ˑn/
a. c-ɛ̀ ↓lóɲ nɛ̂ˑn
PFV-3SG lion see
'(S)he has seen the lion.'
b. c-ɛ̀ ↓lóɲ-dɛ̀ nɛ̂ˑn
PFV-3SG lion-POSS.3SG see
'(S)he has seen her/his lion.'

I propose that the derived contour tone on *nɛ̂ˑn* is a cluster of two level tones. Underlyingly, I claim it has a defective structure in that a L tone is associated to one root node, but the other root node is empty. In the data presented, there are two cases in which the verbal stem gets a HL tone. The first case is when the verb follows a L tone such as an unstable L tone or a possessive marker. In this case, a H tone is inserted which associates to the empty root node to avoid OCP-L violations. This results in a HL tone. The other case is when it follows an unstable noun which is subject to H tone epenthesis. In this case, the HL tone arises through spreading of the inserted H tone.

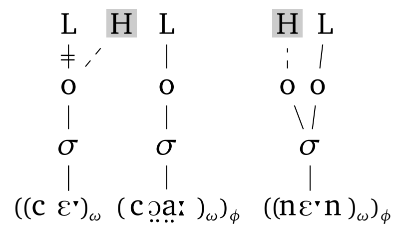
The structure of the verb following stable/hybrid nouns is given first in the examples below. They show the derivations with and without possessives. In (117), the underlying structure is /L#L#L/ which violates the OCP-L. Although H tone epenthesis on the noun *cɔ̤̀a̤ː* would be the most efficient repair of OCP-L, it does not alter its tone because it is linked to the right-most syllable of the p-phrase which includes the auxiliary. Therefore, H tone epenthesis applies to the left, on the auxiliary, and to the right on the verb. The verb stem has two root nodes where one is empty. The inserted H tone can associate to this root node to avoid a L#L sequence between the noun and the verb (117). H tone insertion on the verb is possible because the L tone, which is right-most in the p-phrase, is still preserved.

Stable pattern

(116) Input



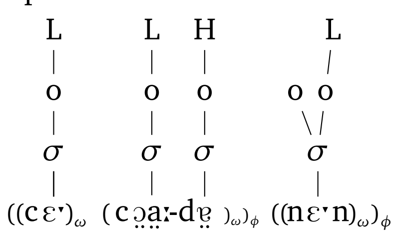
(117) OCP repair



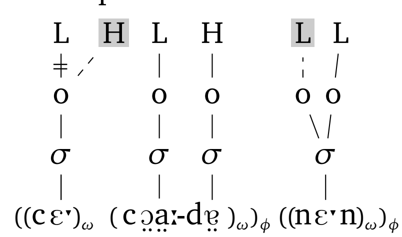
When stable nouns appear with the H-toned possessive marker *-dɛ̤́*, the only OCP-L violation is between the noun and the auxiliary (118). H tone epenthesis applies to the auxiliary, while the left-most root node of the verb gets a L tone (119). For the surface tones, I assume that it is simply a theoretical question whether the empty root node of the verbal stem gets a L tone or remains empty because it is just pronounced as L. Section 10.2.3 will show that root nodes cannot remain empty, and inserting a L tone is cheaper than inserting a H tone at the phrase level. In fact, H tone insertion only applies to avoid OCP-L violations.

Stable pattern

(118) Input



(119) OCP repair

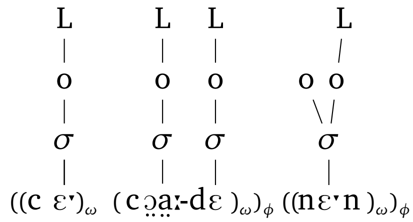


The structure with a L-toned possessive marker is shown in (120). The possessive marker has an underlying L tone. This is evidenced by the fact that it is invariably L independent of surrounding tones. If it were toneless, one would expect that its tone would depend on surrounding tones. Thus, the underlying structure violates the OCP-L three times. These OCP-L violations are repaired by H tone epenthesis on the auxiliary and on the empty node of the verbal stem.

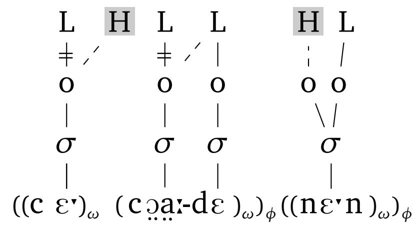
The data show that in addition to right-most L tones of a p-phrase, there is also a tendency to preserve p-phrase medial L tones. Thus, H tone epenthesis only happens to the left-most syllable of a p-phrase and never on stable stems which are p-phrase-medial – see chapter 10 for a discussion of this. It seems that in these constructions, there is another way to repair OCP-L violations which does not involve H tone epenthesis. I propose that the OCP-L repair consists of merging two L tones. The L tone of the possessive marker spreads to the stable stem which delinks its own L tone (121).

Stable pattern

(120) Input



(121) OCP repair

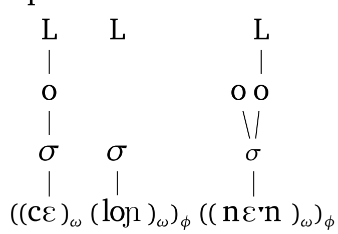


The derivations of the unstable nouns are shown below in (122)–(123). In these constructions, H tone epenthesis does occur p-phrase medially. The reason for this is that inserting a H tone in such a position is considered better than violating faithfulness constraints on underlying L tones which surround the unstable noun.

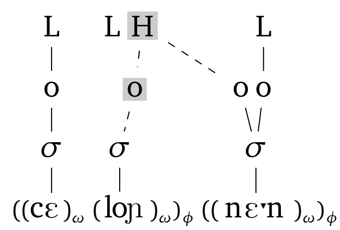
In (122), there is a L#^{L}#L sequence. If the floating L tone links to the noun, OCP-L would be violated twice. In (123), the repair is shown where the epenthesized H tone links to the unstable noun. In order to do this, a root node has to be inserted. This tone also associates to the empty root node of the verb creating a HL tone. The output is a L#H#HL sequence. Thus, the HL tone on the verb arises due to a combination of two factors: OCP-L motivates epenthesized H, but spreading this tone is only possible since there is the empty root node of the verb which needs a tone.

Unstable pattern

(122) Input



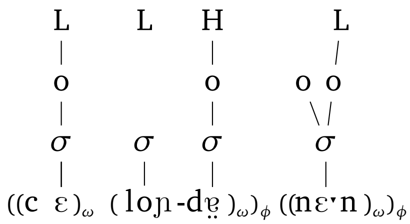
(123) OCP repair



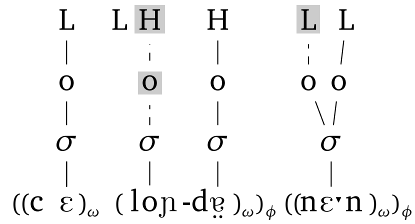
The structure in (124) shows the same sequence as above adding a H-toned possessive marker. If the floating L tone of /^{L}loɲ/ links to its stem syllable, OCP-L will be violated. The repair is to insert a H tone to it and a root node (125). The empty node of the verb gets a L tone because in Nuer grammar, this is better than inserting a H tone, and there are no OCP-L violations between the possessive marker and the verb which could independently motivate H tone insertion – see section 10.2.3.

Unstable pattern

(124) Input



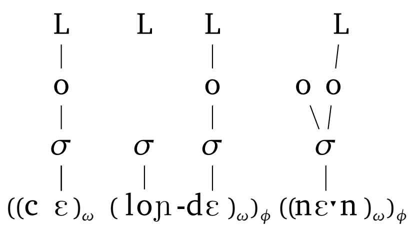
(125) OCP repair



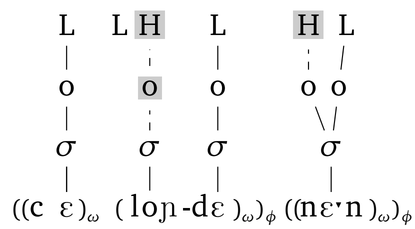
Finally, (126) shows the same structure with a L-toned possessive marker. If the floating L tone of the unstable noun links to its stem, OCP-L will be violated three times. To avoid this, H tone epenthesis applies twice. Association lines cannot be crossed in Nuer so it would be impossible to insert one H tone and spread it onto the verbal stem as in (123) because it would have to cross the association line of the possessive marker. The output is a L#H-L#HL sequence (127).

Unstable pattern

(126) Input



(127) OCP repair



The derivations in this section show some of the mechanisms of H tone epenthesis and why the verbal stem *nɛ̀·n* sometimes shows up with a HL tone. The structural layer of root nodes captures the range of data found in Nuer. They can explain the contrast between lexical HL tones with a unitary structure and cluster contour tones which are derived in the output.

The verb *nɛ̀·n* ‘see’ represents a group of unstable L tone verb stems. Without going into too many details, examples of some more unstable L tone verbs are given below. In (128)–(129), the verbs *ɟɔ̀c* ‘chase’ and *mà·t̪* drink’ appear as L-toned after H- or HL-toned nouns. As expected, the HL tone is again observed on the verbal stem after L-toned nouns in (128c) and (129b). Note that the downstepped H tone on *ꜜc-ɛ́·* in (129b) is due to DOM – see the end of section 5.4.

Unstable verbal stems

(128) a. c-ɛ̀ jâŋ ɟòc /jâŋ/
PFV-3SG cow chase.CF
'(S)he chased the cow away.'

b. c-ɛ̀ mó̤k ɟòc /mó̤k/
PFV-3SG buffalo chase.CF
'(S)he chased the buffalo away.'

c. c-ɛ̀ ꜜlóɲ ɟôc / ᴸloɲ/
PFV-3SG lion chase.CF
'(S)he chased the lion away.'

(129) a. c-ɛ̀ pɥí màˑt̪
PFV-3SG water drink
'(S)he drank water.'

b. ꜜc-ɛ́ˑ pêpsì mâˑt̪
PFV-3SG pepsi drink
'(S)he drank Pepsi.

It appears that verbs can also behave as stable. Where the verbs *ɟoc*, *maˑt̪*, and *nɛˑn* above behave as defective by surfacing with a HL tone after L tones, other verbs do not alter their L tones when they follow L tone nouns. Two examples are given below. The verb *nʊ̀ːŋ* 'bring' has a L tone. This is evident because it is L-toned after both a H tone (130) and after a L tone (131). The latter example shows that the verbal stem behaves as a stable stem by not altering its tone. This is in line with the hypothesis that the right-most syllable of a p-phrase does not alter its underlying tone. Thus, H tone epenthesis is only possible in the cases shown where words have either no underlying tone or an empty root node.

(130) /c-ɛ̀ ɲɛ̤́ˑŋ nʊ̀ːŋ/
c-ɛ̀ ɲɛ̤́ˑŋ nʊ̀ːŋ
PFV-3SG crocodile\PL bring
'(S)he brought the crocodiles.'

(131) /((c-ɛ̀ˑ)$_{\omega}$) (cɔ̤̀a̤ː)$_{\omega}$)$_{\phi}$ ((nʊ̀ːŋ)$_{\omega}$)$_{\phi}$/
ꜜc-ɛ́ˑ cɔ̤̀a̤ː nʊ̀ːŋ
PFV-3SG bone bring
'(S)he brought the bone.'

In addition to stable and unstable L stems, the collected data also contain verb stems with H and underived HL tones. The HL verbal stems are invariably HL after H and L tones (132). The H-toned stems also do not appear to alter their tone depending on the preceding tones (133). This is an indication that these tones are underlyingly linked to the stems which make them 'stable' according to the classification of stems in Nuer.

(132) Unitary HL-toned verb stem

a. c-ɛ̀ lòɲ câm
PVF-3SG eat
'(S)he ate the lion.'

b. c-ɛ̀ kwɛ̤́n câm
PFV-3SG food eat
'(S)he ate the food.'

(133) H-toned verb stem

a. cɛ̤́ˑ t̪ó̤t
PFV-1SG-OM pull.CF
'I pulled it thither.'

b. c-ɛ̀ jâŋ tó̤t
PFV-3SG cow pull
'She pulled the cow'

c. cì-kɛ́n ɛ̄ tó̤t
PFV-3PL OM pull
'They pulled it away.'

5.6 Summary

This chapter presented data related to the OCP-L constraint. I claimed that adjacent L tones are banned in Nuer. The repair mechanism for this is H tone epenthesis. The polar patterns which arise in sequences of L tones reveal a great deal about underlying tones. H tone epenthesis targets toneless suffixes or syllables with a floating tone in the input. I showed that Nuer has unstable stems with a floating lexical tone. If this tone is L, it cannot surface with adjacent L tones. Instead, a H tone is inserted which links to its stem. The floating lexical L tone of these nouns manifests itself by lowering the epenthesized H tone to $^{\downarrow}$H. This pattern contrasts with stable or hybrid nouns which both have an underlying tone at the phrase level. If this is a L tone and appears with adjacent L tones, H tone epenthesis cannot overwrite this tone. Instead, it tries to target other tones. The data indicates that there is a positional preference of retaining p-phrase-final L tones linked to a syllable. Thus, in a p-phrase with two stable L-toned words, the leftmost will get a H tone, while the underlying right-most tone will be preserved. In a p-phrase where a stable L-toned noun appears medially, its L tone merges with the right-most L tone, and H tone epenthesis only applies to the left-most L tone.

Structurally, I adopted root nodes for syllables in Nuer. This structure captures the defectiveness of unstable stems. It also captures the unitary structure of lexical HL tones. For example, lexical HL tones in Nuer do not trigger OCP-L violations on following L tones. This indicates that they are not a cluster of two level tones. Nuer also allows for derived HL tones. These tones surface utterance-finally on defective verbal stems which have an empty root node underlyingly.

The stem classifications will be further elaborated in chapter 7 where I will show that unstable nouns, which are targets of H tone epenthesis, are also targets of floating H(L) and L tonal trees which are inflectional. In contrast, stable and hybrid nouns, which are not targets of H tone epenthesis, are also not targets of these inflectional tonal trees on the stem but receive suffixes. The next chapter explains the acoustics of OCP-L by examining the tone of the verbs and how H tone epenthesis is implemented after L tones.

Chapter 6

Acoustic evidence for OCP-L repair

The previous chapter established that the OCP-L is active post-lexically in Nuer. The unstable verbal stem was discussed in relation to its derived contour tone, which appears after underlying L-toned nouns. Coming back to the studies of chapter 3, the test material there involved carrier sentences with 30 nouns. In two of the four test sentences, these nouns had a H, L, or HL tone and preceded the verbal stem 'see' *nɛ̀ˑn*. This chapter examines the acoustic realizations of H tone epenthesis in Nuer on the verb of these two carrier sentences. This verb stem is an interesting object of f_0 measure because, in these contexts, it shows the effects of both tone sandhi and grammatical tone.

The results presented here show that in an underlying L#L environment of a noun preceding a verb, the verb surfaces with f_0 values which differs in slope and height compared to in a H#L or a HL#L environment. The acoustic measurements indicate a downstepped HL tone on the verb after L-toned nouns. Thus, these results provide evidence of H tone epenthesis by showing how it is phonetically implemented.

The other carrier sentence marks the negative present. This chapter reveals that there is a grammatical tone on the verb stem which is invariably HL. This outcome foreshadows the topic of the next part of this dissertation, namely how tone marks grammatical categories in Nuer. The results show that the verb can either have a L tone or a HL tone depending on the Tense and Aspect marker (TAM). That is, in the perfective, the infinitive verb stem has a L tone. In the present negative, the verb stem has a HL tone. This is another fallout of this study.

This chapter is structured as follows: Section 6.1 presents the methods. This largely refers to the methods of chapter 3 because the material is taken from the experiment reported there. Section 6.2 presents the descriptive and inferential statistical results of H tone epenthesis. Section 6.3 presents a summary.

6.1 Methods

This experiment tests the tone of the verb *nɛˑn* 'see' when it follows an object noun. It examines the same material which was used in the experiment of chapter 3. For more details on the methods – see section 3.2.

6.1.1 Material and measurements

The material measured in this study are the 30 lexical items with H, L, and HL tones – see Table 3.1 in chapter 3. The carrier sentences examined in this study are repeated in (134). The nouns appear in front of the verb stem *nɛˑn* 'see'. The measured targets are the nouns (marked in bold) and the verb stem (underlined). The name of these two sentences is kept the same: *M_L* and *HL_HL*. The TAM of the carrier sentence *M_L* in (134a) is the perfective. After the HL noun *wâːr,* the verbal stem appears as L (*nɛ̀ˑn*), whereas in (134b), the TAM of the carrier sentence *HL_HL* is the negative present and the tone of the verb is HL: *nɛ̂ˑn*.

(134) Carrier sentences

a. cì-kɔ̄n **wâːr** <u>nɛ̀ˑn</u>
PVF-3PL sheep.dung see
'We have seen sheep dung.' *M_L*

b. cí-kɔ̂n **wâːr** <u>nɛ̂ˑn</u>
NEG-3PL\NEG sheep.dung see\NEG
'We are not seeing sheep dung.' *HL_HL*

The elicitation procedure is given in section 3.2.2 of chapter 3. The data set consisted of 60 items and 360 tokens (30 nouns x 2 carrier sentences x 6 speakers). Because of background noises, hesitations, and because some nouns were not familiar to all the speakers, 16 tokens had to be excluded. This resulted in a total number of 344 tokens which were analyzed.

After the data were extracted with Praat scripts and converted into semitones, as was described section 3.2.3, the onset, nucleus, and coda of the target words and of the verb *nɛˑn* were annotated in the Sentence types *M_L* (134a) and *HL_HL* (134b) in order to measure f_0 in the verb. The targets of the nouns preceding the verb and the verb itself was measured to test possible conditionings on f_0 by the tone of the nouns and the Sentence type it appeared in. The slope of the verb nucleus *nɛˑn* 'see' was measured by extracting f_0 at the 1/10th and the 9/10th of the vowel. The initial point was subtracted from the final point of each target.

6.1.2 Statistical analyses

For the descriptive analyses of tone sandhi and grammatical tone, f_0 traces averaged across speakers were plotted on a normalized time axis, as was done for lexical tone on nouns in chapter 3. In the inferential statistics, a Linear Mixed Effects analysis (LME) in *R* with package *lme4* (Bates et al., 2015) was run on the relationship between f_0 of the verb *nɛ˙n* and the two factors Sentence type and Nominal Tone (H, L, and HL). The Nominal tone refers to the object noun preceding the verb. The random variables were Speaker and Noun. The f_0 measurements were of the Height in the vowel onset of *nɛ˙n* (1/10 of the nucleus) and the Slope. These numerical variables were tested separately with the fixed factors. The Sentence type consists of two levels: *M_L* and *HL_HL*. The factors Nominal tone and Sentence type are expected to influence f_0 in the verb, and the null hypothesis is as follows: the f_0 of the nucleus in the verb *nɛ˙n* does not change according to the Sentence type or Nominal tone.

A Linear Discriminant Analysis (LDA) was run with the interaction between Nominal tone and f_0 of the verb (the Height and Slope). The two numerical variables were converted from Hertz to z-scores in the same way as in section 3.2.4 on nouns. The LDA was run on Nominal tone and Sentence type. Based on the results of the LME analysis, the three levels of Nominal tone – H, L, and HL – were collapsed into two levels: +H-tone inducing nouns and –H-tone inducing nouns.

6.2 Results and discussion of verbal tone

This section discusses the effects of H tone epenthesis on the verb stem *nɛ˙n* in the two Sentence types *M_L* and *HL_HL*. The results of f_0 measurements of f_0 Height and Slope are presented below.

6.2.1 Descriptive statistics

The results of H tone epenthesis on *nɛ˙n* are visualized in the plots with f_0 traces below. The corresponding examples of the sentences are given above the plots. Additional plots of the whole sentences can be seen in the Appendix B. In the Sentence type *M_L* in Figure 6.1, the f_0 traces on *nɛ˙n* differ according to whether it follows a L-toned noun, or whether it follows a H- or HL-toned noun. When *nɛ˙n* follows H-toned nouns (solid line) and HL-toned nouns (dashed traces), the traces reach a low target on the nucleus of *nɛ˙n*. For the H-toned nouns, the f_0 trace starts to descend steeply at the beginning of the coda of the target nouns. It continues to drop throughout the onset of *nɛ˙n*. At the boundary of the nucleus of this verb, it is around 6 ST. The dashed line for the HL tones reaches a lower f_0 point earlier as it starts to descend already in the nucleus of the preceding noun. It also reaches 6 ST at the boundary of the nucleus of *nɛ˙n* and overlaps with the solid line. Both traces continue to gradually descend throughout the nucleus of *nɛ˙n*.

For the L-toned nouns (dotted traces), the f_0 trace has a very different shape. A low point is reached in the nucleus of the target nouns as expected. At the end of the target word nucleus, the f_0 trace is about 6 ST high. The f_0 trace then starts to rise from the coda of the target noun. This rise contrasts with traces of the H and HL tones which descend in this area. The dotted line reaches a maximum at the beginning of the nucleus of *nɛˑn*. Exactly at the onset-nucleus boundary, the f_0 trace is almost 7.5 ST high. Although this value is not more than 1–1.5 ST higher than the solid and dashed f_0 traces, it is a notable contrast concerning the shape. That is, the dotted f_0 trace was the lowest of all three traces and has risen to reach its maximum height on the verb. From here, the dotted f_0 trace descends throughout the nucleus of the verb. In other words, L-toned nouns induce a HL falling tone on the verb: *nɛ̂ˑn*. After the H- and HL-toned nouns, it is simply L-toned: *nɛ̀ˑn*. The HL tone is clearly not at the height of the previous H tone but in the middle of the L tone and the H tone. This indicates that H is downstepped to the level of a surface M tone.

(135) *M_L*

a. /cì-kɔ̄n ^{L}loŋ nɛ̀ˑn/
cì-kɔ̄n lòŋ **nɛ̂ˑn**
PVF-3PL lion see
'We have seen the lion.' L-toned noun

b. cì-kɔ̄n mɔ́n nɛ̀ˑn
PVF-3PL soils see
'We have seen soils.' H-toned noun

c. cì-kɔ̄n wâːr nɛ̀ˑn
PVF-3PL sheep.dung see
'We have seen sheep dung.' HL-toned noun

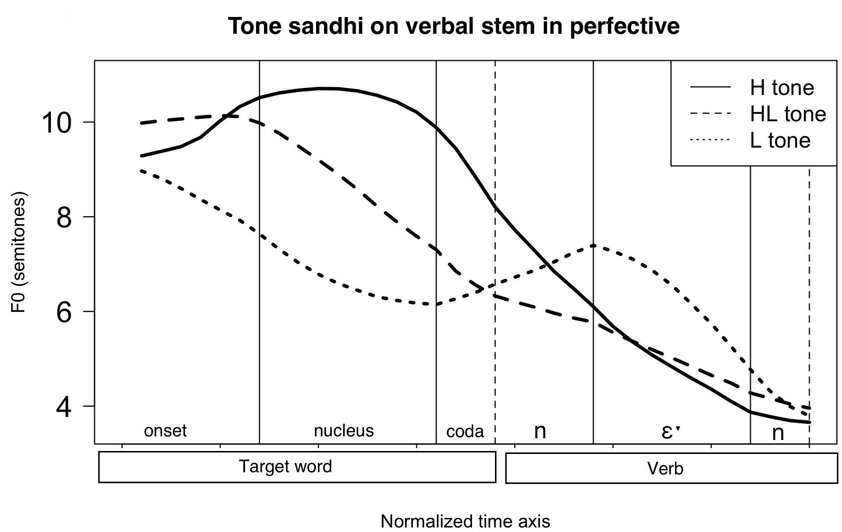


Figure 6.1: F_0 tracks showing H tone epenthesis on the verb *nɛˑn* in Sentence type *M_L* (135). The traces are plotted from average values of all the elicited H, L, and HL nouns of six speakers. The verb follows the target words with H tone (solid line), L one (dotted line), or HL tone (dashed line). The x-axis shows the normalized time, and the y-axis shows the semitone scale of f_0.

In the *HL_HL* Sentence type, the verb has a falling tone independent of the tone of the preceding nouns: *nɛ̂ˑn*. For the solid line, the H tone appears to be subject to declination. It falls very gradually from the nucleus to the onset of the verb, /n/. When it reaches the vowel of the verb /ɛˑ/, it is at the same Height as the dotted line of the L tone target words. The dotted trace of L-toned nouns is low in the nucleus. It reaches its lowest point at approximately 6 ST at the end of the nominal nucleus. From here, it rises up to a high peak in the nucleus of the verb *nɛˑn*. For the HL tone, the dashed trace shows that after the diagonal fall in the nucleus of the noun, the fall flattens out in the coda and onset. It rises to a small degree towards the verbal nucleus. Thus, at the onset-nucleus boundary of *nɛˑn*, all f_0 traces meet and start to fall throughout the verbal nucleus until its coda. These patterns indicate that the negative verb stem gets a falling tone which appears after any lexical tone.

(136) *HL_HL*

a. cí-kɔ̂n lòŋ **nɛ̂ˑn**
NEG-3PL\NEG lion see\NEG
'We are not seeing the lion.' L-toned noun

b. cí-kɔ̂n mɔ́n **nɛ̂ˑn**
NEG-3PL\NEG soils see\NEG
'We are not seeing soils.' H-toned noun

c. cí-kɔ̂n wâːr **nɛ̂ˑn**
NEG-3PL\NEG sheep.dung see\NEG
'We are not seeing sheep dung.' HL-toned noun

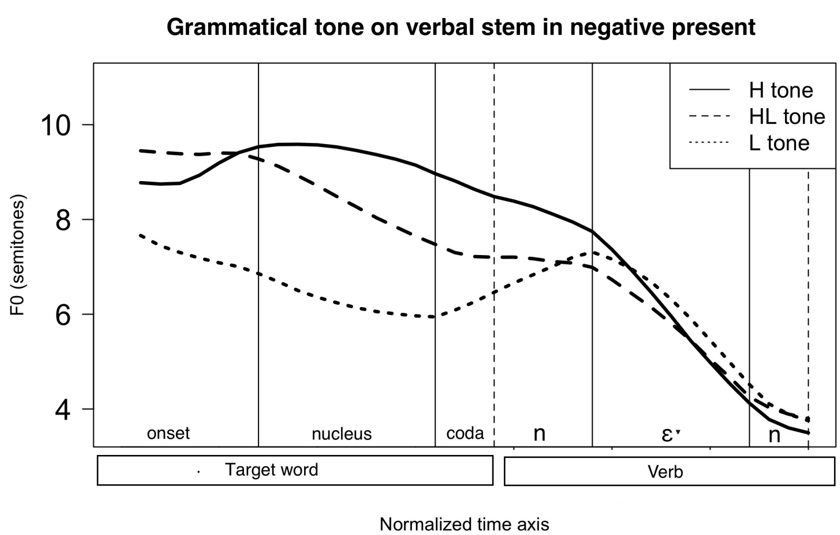


Figure 6.2: F_0 tracks showing H tone epenthesis in Sentence type *HL_HL* (negative present) (136). The traces are plotted from average values of H, L, and HL nouns of six speakers. The verb follows the target words with H tone (solid line), L one (dotted line), or HL tone (dashed line). The x-axis shows the normalized time, and the y-axis shows the semitone scale of f_0.

F_0 Height

The first results presented are the f_0 Height measured of the vowel onset of *nɛ˙n*. The raw data are given in the scatter plot of Figure 6.3 and Table 6.1. A distinct effect of *Nominal tone* is visible for *M_L*, as the f_0 values for *nɛ˙n* are higher when the L-toned nouns precede it (above 7 ST) compared to when the HL- and H-toned nouns precede it (between 5–6 ST). The differences in *HL_HL* are minimal in comparison. Here, the f_0 of *nɛ˙n* does not appear to depend on the Nominal tone. Table 6.1 shows that the mean of *M_L* is around 1.5 ST higher when it follows a L-toned noun compared to when it follows a H- or HL-toned noun. The latter two have about the same mean values. For *HL_HL*, the differences only vary between half a semitone or less.

Nominal tone	M_L		HL_HL	
	mean	sd	mean	sd
H	5.76	1.96	7.44	2.25
HL	5.60	2.12	6.78	2.31
L	7.30	2.28	7.19	2.45

Table 6.1: Mean f_0 values in semitones of the verb *nɛ˙n* preceding either H, L, and HL nouns in two different Sentence types. The measured target is the initial point of the verb nucleus (1/10 into the vowel).

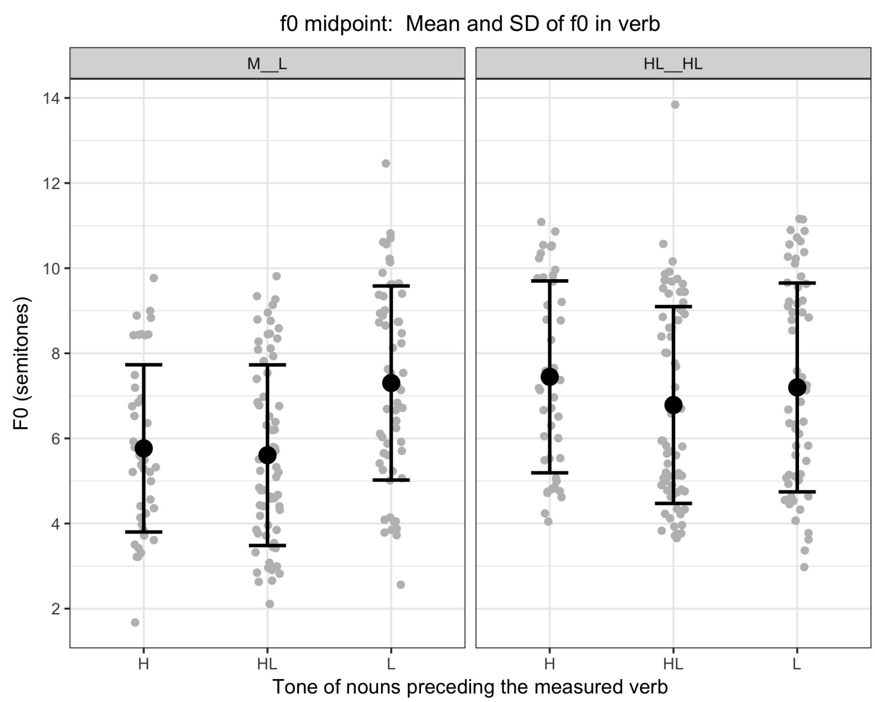


Figure 6.3: Raw data (gray dots) with whiskers of standard deviations and average values (circles). The data points are f_0 measurements of the vowel onset in the verb (1/10 into the vowel). The y-axis shows f_0 in semitones. The x-axis shows the tone of the target words which precede the verb. The interactions with each of the two sentence types are plotted separately.

F_0 Slope

The results of the Slope of the verb are presented below. The average values with standard deviations are given in Table 6.2. In *M_L*, the Slope of the verb is highest when a L tone precedes it (2.1 ST). In comparison, the Slope of *nɛ˙n* following a HL tone is 1 semitone lower (1.1 ST), while the Slope of the verb following a H tone is in between with 1.7 ST.

Thus, the Slope of the verb before a Nominal tone with L is almost double compared to when it precedes a Nominal tone with HL. The Slope of *nɛn* after a Nominal L tone is also larger than its Slope before a H tone, but the difference is not as big. This is expected when considering the graph in Figure 6.1 above. Because the H tone on the noun starts to descend later than the HL tone, the vowel onset in the verb has a higher f_0 value when it follows a H tone compared to when it follows a HL tone. This is only a phonetic effect of the previous targets, and I assume that they both have a L tone in this Sentence type. This assumption is reasonable when comparing the results with the slopes in the Sentence type *HL_HL*. Here, the verb has the biggest Slope when following a H tone (2.9 ST). The HL and L tones are also above 2 ST and hardly differ (2.1 ST vs. 2.3 ST, respectively). As was visible in Figure 6.2, the H tone has a larger Slope because the preceding target is higher. This confirms that the tone on the verb is HL regardless of the tone of the preceding nouns.

The graph in Figure 6.4 visualizes the average values and standard deviations of the Slope in the verb. In Sentence type *M_L*, the Slope is highest when the verb follows a L tone. In Sentence type *HL_HL*, the difference between the verb following HL or L tone is small. The Slope is highest when the verb follows a H tone.

Nominal tone	M_L		HL_HL	
	mean	sd	mean	sd
H	1.71	0.93	2.99	1.23
HL	1.15	0.68	2.19	0.95
L	2.13	1.13	2.30	1.24

Table 6.2: Mean f_0 values in semitones of the verb *nɛ˙n* preceding either H, L, and HL nouns in two different Sentence types. The measured target is the Slope, i.e., the initial point of the verb nucleus (1/10 into the vowel) minus the final point in the nucleus (9/10).

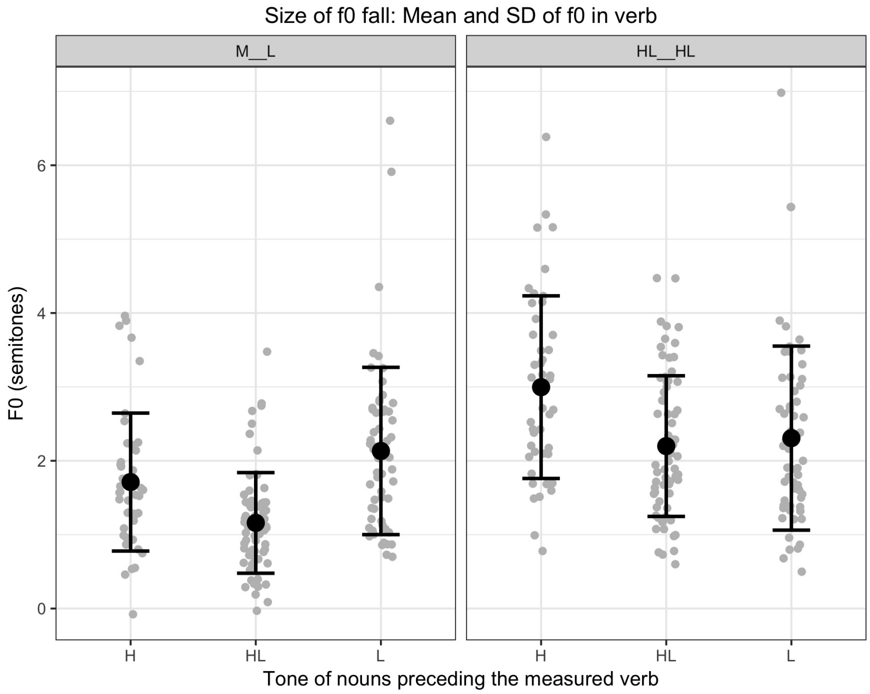


Figure 6.4: Raw data (gray dots) with whiskers of standard deviations and average values (circles). The data points are f_0 measurements of the Slope of the verb (Initial point (1/10) minus final point (9/10) vowel). The y-axis shows f_0 in semitones. The x-axis shows the tone of the target words which precede the verb. The interactions with each of the two Sentence types are plotted separately.

In sum, the descriptive statistics show that the f_0 in the verb differs depending on the Nominal tone in Sentence type *M_L*. This contrast cannot be explained by phonetic effects. That is, the Nominal L tone induces higher values of f_0 Height and Slope on the verb compared when there is a H or HL Nominal tone. This indicates that *nɛ˙n* has a HL tone after L-toned nouns, but a L tone after a H- or HL-toned nouns. The differences between the Height and Slope on the verb after a H- or HL-toned nouns are considered phonetic effects. For example, there is a small-grade falling contour on the verb following a H tone because this preceding H target needs time to reach its low target. For the HL tone, this is not as prominent because it started to decline earlier than the H tone. For Sentence type *HL_HL*, the differences in Slope and Height of f_0 are fairly uniform in comparison and indicate a HL tone on *nɛ̂˙n*.

6.2.2 Inferential statistics

The descriptive statistics indicated that the differences in f_0 Height and Slope depended on both Nominal tone and Sentence type. It is therefore expected that the levels within these factors interact.

F_0 Height

To test the interactions between Nominal tone and the verbal tone, a Linear Mixed Effects Model was run on f_0 Height and Slope of the verb with factors Nominal tone and Sentence type. The random effects were Speaker and Noun. The results are shown below in Table 6.3 and the corresponding plot is shown in Figure 6.5. The mean values of the two Sentence types are shown by a solid line with circles (*M_L*) and a dotted line with triangles (*HL_HL*). The plot shows the effects of Nominal tone and Sentence type on f_0 Height of the verb. The two Sentence types do not interact except when Nominal tone is L. When the Nominal tone is H or HL, the f_0 Height of *nɛ˙n* is between 5.5–6 ST. When L is the Nominal tone, f_0 rises to above 7 ST. For *HL_HL*, the differences in Nominal tone of the preceding nouns varies much less ranging from approximately 6.75–7.5 ST. The biggest difference in this Sentence type lies between HL and H. This is still a small difference in f_0 compared to the differences between L vs. H and HL in *M_L*.

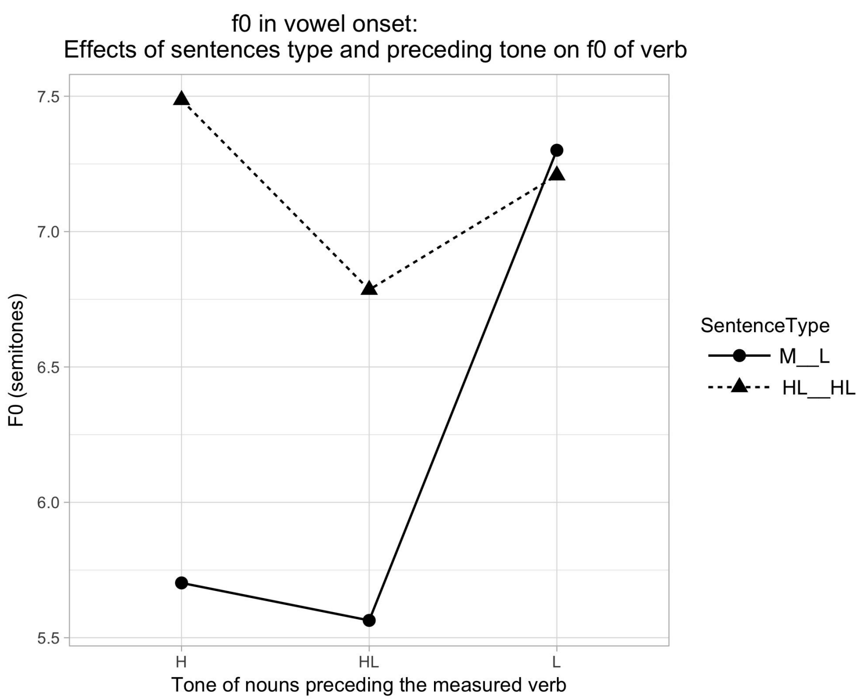


Figure 6.5: Plotted effects of $f_0 \sim$ Nominal tone * Sentence type. The f_0 measurements are of the vowel onset in the verb *nɛ˙n* (1/10 into the vowel). The y-axis shows the f_0 in semitones which was measured in the nucleus of *nɛ˙n*. The x-axis shows the tone of the nouns which precede *nɛ˙n*: H, HL, or L.

The results of the lmer model in Table 6.3 below show the effect on f_0 by factor levels H, L, and HL tones, as well as Sentence types *M_L* and *HL_HL*. Intercepts with different factor levels were used to get full comparisons. That is, two different tone levels are used as the intercept for each Sentence type. When *HL_HL* and the HL tone are the intercepts, the estimate is 6.78 ST which is the average value of HL tones appearing in *HL_HL* – see Table 6.1. The H tone is 0.70 ST higher than this intercept ($p<0.008$). The L tone, on the other hand, does not differ significantly from it ($p=0.08$) and is only 0.42 ST higher. The plot in Figure 6.5 showed that the biggest difference was between H and HL tones in *HL_HL*. This was also addressed in the descriptive statistics; namely, that f_0 is higher in the vowel onset because the H tones of the preceding nouns start to descend later compared to the HL tone. Sentence type *M_L* is significantly lower than the intercept by 1.22 ST ($p<0.001$). Because the intercept is the HL tone, the comparisons are between the verb following HL tones in *M_L* vs. *HL_HL*. This supports the observations that the verb has a L tone in the former Sentence type and a HL tone in the latter Sentence type. The difference between HL and L tones are greater in *M_L* than in *HL_HL* by 1.31 ST ($p<0.001$). In fact, as observed in Figure 6.5, HL and L tones hardly differ in *HL_HL* compared to in *M_L*. When the intercept is the H tone in Sentence type *HL_HL*, the L tone differs from it by only −0.27 ST and is non-significant ($p=0.3$). Sentence type *M_L* differs significantly from the intercept by −1.78 ST ($p<0.001$). This supports the interpretation of a L tone on the verb in *M_L*. The interaction between Nominal L tone and Sentence type *M_L* is significant and has an estimate of 1.87 ST ($p<0.001$). This shows that the difference between L tones and H tones is significantly greater in *M_L* compared to in HL_HL (the intercept). This is expected under the interpretations that the verb has a HL tone after L-toned nouns in *M_L*, and a L tone after H-toned nouns in *M_L*. The tone of the verb is, however, the same in *HL_HL*.

When factor level *M_L* and HL tone is the intercept, the estimate is 5.70 ST. Again, this corresponds to the average value of f_0 of HL tones in the Sentence type *M_L* (see Table 6.1). When the H tone precedes the verb, f_0 does not differ significantly from the intercept and is only 0.13 ST lower ($p=0.59$). On the other hand, when L tones precede the verb, f_0 differs significantly from this intercept and is 1.73 ST higher ($p<0.001$). This is expected in *M_L* because the verb following a H or HL tone was observed to have a low tone, and the verb following a L tone had a HL tone. When the H tone in Sentence type *M_L* is the intercept, the L tone differs significantly from it by 1.59 ST ($p<0.001$).

Fixed effects:	Estimate (ST)	Std. Error	df	t value	Pr(> |t|)
Intercepts with Sentence Type: HL_HL					
(Intercept = N. HL tone)	6.78	0.82	5.34	8.26	0.000307 ***
N.tone H	0.70	0.25	83.58	2.69	0.008420 **
N.tone L	0.42	0.24	80.59	1.75	0.082719 .
SentenceType M_L	-1.22	0.21	307.25	-5.60	4.63e-08 ***
N.tone H: SentenceType M_L	-0.56	0.34	307.78	-1.61	0.107031
N.tone L: SentenceType M_L	1.31	0.32	307.1	4.08	5.61e-05 ***
(Intercept = N. H tone)	7.48	0.82	5.57	9.02	0.000157 ***
N.tone L	-0.27	0.26	82.86	-1.03	0.303975
SentenceType M_L	-1.78	0.27	308.11	-6.57	2.11e-10 ***
N. Tone L: SentenceType M_L	1.87	0.36	307.66	5.21	3.43e-07 ***
Intercepts with Sentence Type: M_L					
(Intercept=N. HL tone)	5.56	0.82	5.35	6.77	0.000812 ***
N.toneH	0.13	0.26	86.98	0.52	0.59936
N.tone L	1.73	0.24	83.07	7.14	3.13e-10 ***
(Intercept=H N.tone)	5.70	0.83	5.59	6.86	0.000635 ***
N.tone L	1.59	0.27	85.75	5.88	7.45e-08 ***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Formula: Vowel onset_ST ~ N.tone * SentenceType + (1|Speaker) + (1|Noun)					

Table 6.3: Results of Linear mixed model fit by REML. T-tests use Satterthwaite's method. Tested interactions between f_0 in the nucleus of the verb and N(ominal) tone * Sentence type.

In view of these results, the null hypothesis is rejected. The most important results of the tested factor levels are that in *M_L*, f_0 in the verb following L tones differ significantly from H and HL tones, while it does not differ significantly when H and HL tones precede the verb. In *HL_HL*, f_0 of the verb following a L tone does not differ significantly compared to when it follows a H or the HL tone. When it follows a H tone, the effect is significantly different from when it follows a HL tone. However, this effect is, first of all, not significant (p=0.08). Second, it is not significantly different from the f_0 Height of verbs following L tones. This supports the phonetic nature of this effect which was mentioned in the descriptive statistics. That is, the HL tone starts to descend late into the vowel of the noun and by the time the tone reaches the verb, f_0 is higher compared to the HL.

F_0 Slope

The Slope of the fall in the verb is also expected to differ according to Nominal tone (the tone of the noun it follows) and the Sentence type. If a HL tone is induced on the verb, the Slope is expected to be large. If the verb has a L tone, the Slope is expected to be significantly smaller. However, there are two reasons why a positive value of the Slope is still expected for L tones in the verbs. One reason is that when the previous targets are H or HL tones, the tone arrives from a high point and has not yet reached a low point when it arrives at the verb. This was observed in section 6.2.1 on descriptive statistics. The second reason is that the verb is sentence-final. As was observed in section 3.3, final L tones undergo a phonetic final lowering, which especially effects L tones. For these two reasons, L-toned verbs are still expected to have a Slope of positive value, but it is expected to be significantly smaller than the Slope of verbs with a HL tone.

The effects plot in Figure 6.6 shows the differences in f_0 Slope depending on Sentence type and Nominal tone of preceding nouns. This plot is similar to the one in Figure 6.5 in that the two sentence types are on different planes and do not interact. Overall, the plot shows that the Slope is bigger in Sentence type *HL_HL* compared to *M_L*, except for the L tone where it almost overlaps. This confirms the tones observed on the verb in the descriptive statistics: in *HL_HL*, the verbs have a HL tone regardless of the tone of the verb it follows. In *M_L*, the verb is L-toned after H and HL nouns, but HL-toned after L-toned nouns.

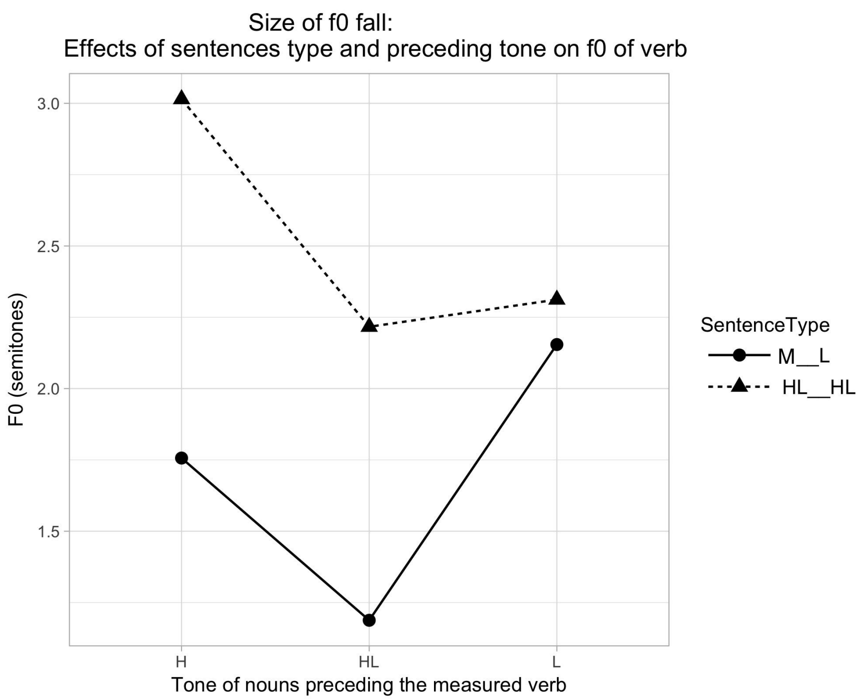


Figure 6.6: Plotted effects of $f_0 \sim$ Nominal tone * Sentence type. The f_0 measurements are of the Slope of the verb vowel *nɛ˙n* (1/10 point in the vowel minus 9/10). The y-axis shows the f_0 in semitones which was measured in the nucleus of *nɛ˙n*. The x-axis shows the tone of the nouns which precede *nɛ˙n*: H, HL, or L.

In more detail, Figure 6.6 show that the Slope of the Nominal L tones in the two sentence types have close values but their data points do not overlap. The Slope of the L tone is slightly below 2.25 ST in Sentence type *M_L* (solid line) and slightly above 2.25 ST in *HL_HL* (dashed line). This Slope has about the same size as the verb after HL tones in *HL_HL*. This supports the fact that the HL tone on the verb is the same when it follows L-toned nouns in *M_L* as when it follows HL- or L-toned nouns in *HL_HL*. There is a clear contrast to the Slope of the verb following a HL-toned noun in Sentence type *M_L*. Here, the Slope is nearly half the size of the Slope of the verb following L tones and close to 1 ST. This confirms the L tone pattern seen in *M_L* after HL-toned nouns. The fact that there is still a Slope around 1 ST confirms the final lowering on the verb which has a level tone. The Slope of the Nominal H tones is the largest at approximately 3 ST in *HL_HL*. In Sentence type *M_L*, the Slope is almost half the size and lies at approximately 1.75 ST. This indicates that a L tone on the verb with a phonetic falling contour which is due to final lowering. The distance in the graph between the Slope of the verb following H tones in *HL_HL* vs. *M_L* is parallel to the contrast between the Slope in the verb following HL tones in these two sentence types.

The results of the Linear Mixed Effects model is given in Table 6.4 below. Four intercepts are shown with different reference levels of Sentence type and Nominal tone in order to compare all levels of the factors. First, the intercept in Sentence type *HL_HL* with tone HL is shown with the estimate 2.21 ST. The H tone deviates significantly from this being 0.79 ST higher ($p<0.001$), but not the L tone as it is only 0.09 ST higher ($p=0.49$). This confirms that the verb is HL after any tone, but the Slope is bigger when the tone it follows is H. The Sentence type *M_L* deviates significantly from the intercept by −1.02 ST ($p<0.001$). This supports the assumption that the verb following a HL tone is L in *M_L*. The interaction between Nominal H tone and Sentence type M_L is non-significant ($p=0.27$). This indicates that the difference between H and HL tones is approximately the same in Sentence type *M_L* compared to in *HL_HL*. This is a useful comparison. In fact, the plot in Figure 6.6 showed that the differences between HL and H tones in *M_L* is parallel to the difference between these tones in *HL_HL*.

Fixed effects:	Estimate (ST)	Std. Error	df	t value	Pr(> |t|)
Intercepts with Sentence type: HL_HL					
(Intercept = N. HL tone)	2.21	0.31	5.79	6.96	0.000507 ***
N.tone H	0.79	0.15	92.58	5.27	8.70e-07 ***
N.tone L	0.09	0.14	89.33	0.68	0.496763
SentenceType M_L	-1.02	0.13	307.07	-7.79	1.04e-13 ***
N.tone H: SentenceType M_L	-0.22	0.21	307.66	-1.08	0.276954
N.tone L: SentenceType M_L	0.87	0.19	306.90	4.46	1.11e-05 ***
(Intercept = N. H tone)	3.01	0.32	6.37	9.25	6.32e-05 ***
N.tone L	-0.70	0.15	91.77	-4.48	2.14e-05 ***
SentenceType M_L	-1.25	0.16	308.03	-7.65	2.57e-13 ***
N.tone L: SentenceType M_L	1.10	0.21	307.52	5.04	7.81e-07 ***
Intercepts with Sentence type: M_L					
(Intercept = N. HL tone)	1.18	0.31	5.82	3.72	0.010309 *
N.tone H	0.56	0.15	96.58	3.71	0.000342 ***
N.tone L	0.96	0.14	92.08	6.82	9.23e-10 ***
(Intercept = H tone)	1.75	0.32	6.41	5.38	0.001369 **
N.tone L	0.39	0.15	95.24	2.50	0.013791 *
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Formula: Slope_ST ∼ N.tone * SentenceType + (1 | Speaker) + (1 | Noun)					

Table 6.4: Results of Linear mixed model fit by REML. T-tests use Satterthwaite's method. Tested interactions between the Slope of f_0 in the nucleus of the verb and N(ominal) tone + Sentence type.

Furthermore, Table 6.4 shows that the interaction between Nominal L tone and Sentence type M_L is significant and has an estimate of 0.87 ST ($p<0.001$). This shows that the difference between the verb following a L tone compared to when it follows a HL tone is significantly bigger in Sentence type *M_L* compared to *HL_HL*. This was observed in the plot; namely, that the Slope of the verb following a L tone in *M_L* is about double the size than when it follows a HL tone. For *HL_HL*, the Slope is about the same.

When the intercept involves Nominal H tone in Sentence type *HL_HL*, the estimate is 3.01 ST. The L tone deviates significantly from this by -0.70 ST ($p<0.001$). This shows that the Slope of the verb following a H tone is higher than when it follows a HL or L tone. The measurements of f_0 Height in the vowel onset of the verb showed the same outcome and was also significant (see Table 6.3). The reason for this is assumed to be phonetic. Sentence type *M_L* deviates significantly from the intercept by -1.25 ST ($p<0.001$). This is almost half of the intercept and supports the interpretation of a L tone on the verb. The interaction between Nominal L tone and Sentence type M_L is significant and differ by 1.10 ST ($p<0.001$). This shows that the difference between the verb following L tones and H tones is greater in *M_L* compared to in *HL_HL*. This comparison is important because it supports the interpretation that the difference of the Slope in the verb following L tones and H tones is phonological in *M_L* (HL vs. L), while it is phonetic in *HL_HL* (HL in both cases).

Furthermore for Table 6.4, when the intercept is Nominal HL tone in Sentence type *M_L*, the estimate is 1.18 ST. This corresponds to a L tone on the verb. When the verb follows a H tone, the Slope is 0.56 ST higher and differs significantly from the intercept ($p<0.001$). When L tones precede the verb, the difference is 0.96 ST from the intercept and significant ($p<0.001$). Although both the H and the L tones are significantly higher than the intercept, the estimate of the L tone is bigger than the H tone. This is interpreted as following: the Slope of the verb following H tones is a phonetic effect, while the Slope of the verb following a L tone is due to a HL tone. When the intercept is Nominal H tone in *M_L*, the estimate is 1.75 ST. Nominal L tone significantly differs from this estimate by 0.39 ST ($p<0.01$). This is not a big difference in semitones because of the phonetic effect which Nominal H tones create on Slope of the verb.

In sum, the results of the Slope show that there are interactions between the tone levels and Sentence types. They support the interpretations that the verb following L and HL tones do not differ significantly in *HL_HL* as the tone is simply HL, i.e., the verb following H tones have a higher Slope but is still HL. In *M_L*, the Slope of the verb following L tones is significantly different from when it follows HL tones and H tones. The is argued to be because the verb has a HL tone. The Slopes of the verb after H and HL tones is lower, indicating a L tone. There is, however, a phonetic effect which makes the Slope following H tones higher, but not as high as after L tones.

The Linear Discriminant Analysis tested how f_0 values of the verb in Sentence type *M_L* could predict the tones. A data subset was tested with two groups of tones. The levels H and HL tones were collapsed into the level 'non-sandhi-inducing tones'. The L tone was the sandhi-inducing tone. The results showed that f_0 Slope and Height of the verb (converted into z-scores) can predict the correct classification of these tone groupings in *M_L* with 75.8%. This is fairly high above the chance-level baseline at 50%.

6.3 Summary

This chapter provided instrumental evidence for H tone epenthesis. The results of the descriptive and inferential statistics on verbal tone show that f_0 in the verb differs significantly depending on which tone the preceding nouns have, and which Sentence type it is pronounced in. The sentence *M_L* has an auxiliary which ends in a M tone, and the TAM is perfective. Here, the verb stem is L-toned after H- and HL-toned nouns: *nɛ̀ˑn*. Nouns with a L tone, on the other hand, induce a falling tone on the verb: *nɛ̂ˑn*. These results confirm the proposal in chapter 5 that H tone epenthesis occurs in sequences of L tones. Thus, this phonological rule is responsible for the falling tone on the verb. The phonetic realization of the HL tone is lower than the preceding H tones. The f_0 level of the peak had a M tone value corresponding to [ꜜHL]. The nature of this downstep is assumed to be automatic and induced by the surface L tones of the previous nouns. That is, there are only assumed to be linked L tones in the tested sentences since it is the output of the phrase level.

The Sentence type *HL_HL* has an auxiliary ending in a HL tone. In this Sentence type, the verb has a falling tone regardless of the tone which precedes it: *nɛ̂ˑn*. Therefore, I assume that this is a morphological tone conditioned by the negative form in the present tense. More specifically, I claim that the underlying lexical tone of this verb is L. At the phrasal level, a HL tone surfaces when the negative form of the verb is formed.

Comparisons with neighboring languages show that Nuer is not alone in marking the infinitive verb form for negation. In Dinka, infinitives with a short vowel which are 'unmarked', i.e., the verb form used with a topical subject, have a L tone in the affirmative form. In contrast, the negative form of the infinitive has a H tone (Andersen, 1995; Remijsen and Ladd, 2008).

Part III

Grammatical Tone

Chapter 7

Case and number inflection

This chapter presents data on inflectional tone in Nuer. This part of the grammar is particularly interesting because inflectional tone interacts with lexical tone and OCP-L. The observed patterns from this chapter will be analyzed in chapter 9.

Nominal inflection is known to be the most irregular part of the grammar of Western Nilotic languages. There are many parameters involved in inflecting a noun from one category to another. The degree of complexity of inflection patterns in Nuer and its neighboring languages has been discussed by several scholars such as Ladd et al. (2009); Trommer (2011); de Lacy (2012); Baerman et al. (2017), among many others. Nuer has received attention particularly regarding its 'chaotic' distribution of suffixes in nominal inflection (Frank, 1999; Baerman, 2012). These studies show a type of suffix allomorphy which did not seem to be phonologically or semantically driven – see section 1.1.2.

The data presented in this study on the Eastern Jikany dialect spoken in Ethiopia are very different from these previous studies on Nuer. One notable outcome of my investigation is that the suffix distribution is much more regular with only five different surface patterns compared to the 24 observed in Baerman (2012). This difference depends mostly on the dialect of this study where the locative and genitive case have the same forms. However, the most important result is that the surface distribution of suffixes does not rely on arbitrary classes but can be predicted by the tonal properties of the stems. Chapter 5 showed that Nuer has unstable stems which have a floating lexical tone and are subject to H tone epenthesis in cases of OCP-L violations. In contrast, the so-called stable stems have a fully specified tone and are immune to H tone epenthesis in certain prosodic positions. In this chapter, I show that the phonological-based distinction of stems can predict the distributions of suffixes. That is, stable nouns get a suffix because they are fully specified, while unstable nouns cannot take a suffix and are instead overwritten by inflectional tones because they are defective. In this way, non-linear exponence involving stem-internal modifications is connected with the underlying tone specifications of nouns. In the remainder of this chapter, I give a brief background on number inflection in

Western Nilotic in section 7.1. In section 7.2, I introduce the distribution of inflectional suffixes and compare this with some of the data in Frank (1999). I claim that there are three stem distinctions which are necessary in Nuer to predict inflectional tone and suffixation. In section 7.3, I discuss exponence in number inflection and show that H tones are prevalent in plural marking. In section 7.4, I present evidence of a L tone pattern in the oblique case. Section 7.5 shows how these oblique L tones violate OCP-L and result in different repair mechanisms depending on the stem types. The final generalizations on exponents and how they interact with stems are given in section 7.7.

7.1 Background on number inflection in Nilotic

In the Nilo-Saharan language family, the complexity of inflection is mainly due to a 'tripartite' number marking system which is prevalent in languages of this family (Dimmendaal, 2000). That is, the singular, the plural, or both forms can be the morphologically modified or marked one. For this reason, it is common in the Western Nilotic literature to refer to 'simple' or 'unmarked' as morphologically base forms and 'complex' or 'marked' as morphologically modified or inflected forms. This bidirectional pattern gives four possible morphological forms in number: simple singular stems, complex singular stems (derived from plural), simple plural stems (underived), and complex plural stems (derived from singular) (cf. Andersen, 2014; Storch, 2005; among others). The simple vs. complex forms can sometimes be semantically motivated in that mass nouns are typically simple in the plural, while nouns which are typically countable are complex in the plural (Dimmendaal, 2000).

To illustrate the tripartite system, consider the three nouns in (138)–(139) in Mayak, a dialect of the Western Nilotic language Burun. Starting with the most common way of number marking, the noun 'crocodile' in (137) has an unmarked singular form which becomes plural by adding a suffix. In (138), the collective form of 'teeth' is the unmarked form which derives the singulative by adding a suffix. Finally, the third kind of derivation can be observed in (139) where both the singular and the plural have a suffix and are marked forms. This is referred to as the 'replacement pattern'.

(137)	Singular	Plural		
	jaaŋ	jʌŋ-in	'crocodile'	Plural formation
(138)	Singulative	Collective		
	leɣ-it̪	lɛk	'teeth'	Singulative formation
(139)	Singular	Plural		
	gaal-at̪	gʌl-uk	'hand,arm'	Replacement pattern

Mayak (Storch, 2005: 99)

The bidirectional way of marking plural in is also known as morpho-phonological polarity: "[...] a situation where $/\alpha/ \rightarrow [\beta]$ and $/\beta/ \rightarrow [\alpha]$ in a particular morphological context in the same phonological environment." (de Lacy, 2012: 121).

7.1.1 Dinka

Dinka has many similarities with Nuer. As is common in Western Nilotic languages, number formation is often derived by stem-internal mutations alone. Systematic changes have been found in the stem alternations of verbal and nominal inflection of Dinka and Mayak. This is referred to as vowel grades and can be described as a 'morphological stratification' system (see Andersen 1993, 1999, 2002). Andersen defines this as a system where stem vowels alternate in vowel and voice quality. In Dinka, Andersen (2002: 3) observes that "[g]rade 1 is the basic grade, which most directly reflects the lexical quality of the root vowel." Briefly put, grade 2 and grade 3 are derived by morpho-phonological rules which alter the vowel quality. Grade 2 is derived from grade 1, and grade 3 can be derived from either grade 1 or grade 2.

The number formation has been well studied in Dinka. According to Andersen (2002) and Ladd et al. (2009), the differences between the singular and the plural in Dinka are irregular and synchronically unpredictable. However, they note many subregularities.

First, morphologically complex forms in Dinka which have stems with overlong, breathy and/or grade 2 or grade 3 vowels tend to have a contour tone. In contrast, basic forms have a level tone (Andersen, 2002)[1]. Some examples of this are given below in (140)–(143).[2]

Complex forms with HL tones

Simple forms: level tones

(140) Singular

a. dò̰m 'field'

b. mà̰ˑc 'fire'

(141) Plural

a. lḛ̀c 'teeth'

b. ywò̰ˑm 'bones'

Complex forms: contour tones

(142) Plural

a. dṳ̂ˑm 'fields'

b. mɛ̤̂ˑc 'fires'

(143) Singular

a. lê̤ˑc 'tooth'

b. ywɔ̰̂ːm 'bone'

Dinka (Andersen, 2002)

The second subregularity which is relevant for this study is a polar pattern where one form (either singular or the plural) has a L tone, and the other form has a H tone. Although Ladd

[1] See also (Storch, 2005).

[2] The examples from secondary sources have been modified so that vowel length is transcribed as in Nuer: zero, one, or two length marks in IPA.

et al. (2009) note that this polar pattern is more or less equally distributed between singular and plural forms, data indicate that H tones are more prevalent in plural forms. For example, collective nouns in Dinka, which are considered underived plurals, are H- or L-toned and get a HL tone plus vowel lengthening in the singularized form (Storch, 2005: 178). From the available data, it appears that collective CVC stems alternate between having a H tone as in (145a)–(145b) or a L tone as in (145c). The CVˑC stems, however, appear to have a more regular H tone pattern as shown below in (147).

H tone on plurals – singularized forms with HL tone

(144)	Singularized: HL	(145)	Collectives: H/L	Gloss
	a. ’byôˑk		a. byók	‘animal hide’
	b. ’ryɛ̂ˑm		b. rím	‘blood’
	c. wɛ̂ˑr		c. wàr	‘dung’

(146)	Singularized: HL	(147)	Collectives: H	Gloss
	a. ‘cḭ̂ˑn		a. cḭ́ˑn	‘intestines’
	b. ‘nʊ̂ˑn		b. nʊ́ˑn	‘grass’
	c. ‘pʊ̂ˑr		c. pʊ́ˑr	‘hoes’

Dinka (Storch, 2005: 178,181)[3]

For complex plural forms, the stems commonly have a grade 2 vowel derived from grade 1 vowels in the singular form (Storch, 2005). The monosyllabic stems in the plural tend to have a H tone (149) while the singular forms have either a H or a L tone (148).

H tone on plurals

(148)	Simple SG: H/L	(149)	Complex PL: H	Gloss
	a. bà̤ˑy		a. ‘bɛ̤́ˑy	‘house’
	b. kwá̤l		b. kwɛ̤́l	‘star’
	c. màc		c. mɛ́c	‘fire’

Dinka (Storch, 2005: 182)

Complex forms of both singular and plural can have a grade 3 vowel (Storch, 2005). These data indicate that complex plurals again have more of a consistent H tone pattern on monosyllabic stems compared to complex singulars.

[3] Note that Storch assumes there are stress differences in the stems which she annotates with the acute accent (’).

(150)	Simple SG	(151)	Complex PL: H tone	Gloss
	a. kṳl		a. kwṓl	'leg'
	b. dít		b. dyɛ́t	'bird'
	c. cò˙r		c. 'cwɔ́r	'eagle'

Dinka (Storch, 2005: 183)

In sum, some of the subregularities in Dinka number marking are that contour tones correlate with stem complexity in that overlong, breathy, and/or grade 2 or 3 vowels tend to have a contour tone. Data from Dinka indicate that plural forms often have a H tone. Dinka is not the only Western Nilotic language where H tones appear in the plural. In Shilluk, H tones appear in the plural of the head-marked form referred to as pertensive – see section 7.6.2 for a discussion on head-marking.

7.1.2 Nuer

For Nuer, Storch (2005: 198–99) makes several observations concerning stem complexity which are similar to the system in Dinka. For example, that simple singular nouns are mainly monosyllabic and that for number pairs which contrast in vowel length, stems with long vowels are complex. Just as in Dinka, Storch notes that collective nouns have CVC forms and the singularized forms are derived by adding a mora (CV˙C), either by diphthongization or by keeping the monophthong.

Storch makes a few observations on Nuer which are relevant for this study. First, a vowel change from modal to breathy indicates a morphologically complex stem vowel (Storch, 2005: 202). Section 7.3.2 shows that this is prevalent in Nuer. Second, she claims that morphological complex plurals are most commonly derived from singular forms by adding a suffix or by the following stem-internal alternations: vowel grade alternation, diphthongization, vowel lengthening, and/or voice alternation (Storch, 2005: 208). In this study, adding a suffix is the most productive way of forming a plural.[4]

Third, Storch (2005: 200–201) reports that stem-final consonant mutation in Nuer is a process which can be traced back to an old suffixing system, which is still found in neighboring languages. Based on diachronic evidence, she refers to these consonant mutations as suffixation. For example, she claims the change from /l/ in the singular form of 'goat' *dɛ́l* to /t/ in the plural form *dḛ̀t* is suffixation of the plural marker *-t*.[5] She notes that this consonant suffix is also considered to be responsible for the change of the stem vowel from ɛ to e̤. Although some of the singular and plural nouns show coda alternations, I argue in section 7.3.2 that consonant mutation is not a productive process in this study.

[4]Storch (2005) claims that the suffix has two allomorphs: *-ni* and *-ní* which harmonize according to ATR harmony. In this study, there is only one *-ni̤*.

[5]There are many differences between the data in Storch (2005) and this study. For example, the tones of 'goat/sheep' differ: *dɛ̂˙l* and *dḛ́t*.

7.2 Suffixation and stem classes

Number marking in this study on Nuer involves both suffixation and stem-internal modifications. I first show the suffixation patterns I have found and compare them with the study by Frank (1999) before proposing three stem distinctions in Nuer: stable, unstable, and hybrid.

7.2.1 Comparison of data

In this study, the locative and genitive forms are segmentally and tonally identical and collectively referred to as the oblique case (OBL). This drastically reduces the number of noun classes and is the main reason why this study differs so greatly from the study by Frank (1999) where the genitive and locative have mostly different forms – see section 1.1.2. In addition, the current data are segmentally different from Frank's data.

It is not entirely clear why the studies are so different. However, it is reasonable to assume that the differences lie in the dialects of the speakers. Both this study and Frank (1999) are on Eastern Jikany Nuer. However, as was mentioned in section 1.1, dialectal differences in Nuer are not studied. Eastern Jikany Nuer covers a fairly large area located in both south-western Ethiopia and the Upper Nile state of South-Sudan. It is entirely possible that the Jikany 'variety' in Ethiopia is different from the Jikany variety in South Sudan. This study is specifically on the Ethiopian variant of Jikany Nuer, while Frank (1999) worked with an Eastern Jikany speaker from Nasir in the west in South Sudan at the border of Ethiopia. It is possible that the genitive and the locative case has formed one category only in the Ethiopian variety of Nuer shown here. In another dialect of Nuer, Lɔu, there are distinct forms in the genitive and locative cases (Reid, p.c.). Another plausible reason is language change. The data of this study was collected between 2016–2017 while the data of Frank's study was collected in periods between 1997–1998. Perhaps today, the Eastern Jikany Nuer spoken in Nasir has also collapsed the genitive and locative into one category.

A few of the differences between this study and Frank (1999) can be observed below in Table 7.1. For the noun 'shoulder', the singular and plural of the nominative case have different forms in both studies. In the singular form of the locative and genitive case, there are two different forms, and they differ in the vowel quality of the stem. In the current study, there is only one form: *wṳ́ˑk-ɛ̤̀*. In the plural forms of genitive and locative case for this noun, there is only one form in both studies. The opposite can be observed for the noun 'lion' where the plural forms of the locative and genitive case are different in the plural in Frank (1999), but the same in the singular. Again, in this study, they have the same form in both the singular and plural. For the noun 'bone', there are only four forms in both data sets because the genitives and locatives are identical in both the singular and plural in Frank. However, the data differ segmentally concerning the coda and vowel length. For example, the singular nominative form has a coda in Frank (*cɔɣ*), while it has an open long vowel in this study (*cɔ̤̀a̤ː*).

Gloss	Data	NOM SG	NOM PL	GEN SG	LOC SG	GEN PL	LOC PL
‘shoulder’	Frank (1999: 84)	wuɔ̱k	wuɔ̱ɔ̱k	wuɔ̱kkä	wuukä	wuɔ̱ɔ̱kni̱	
	Current study	wɔ̤́ˑk	wɔ̤́ːk	wṳ́ˑk-ɛ̤̀		wɔ̤́ːk-nì̤	
‘lion’	Frank (1999: 87)	lony	luony	lony		luonyni̱	luony
	Current study	lòɲ	lûɔˑɲ	lùɔˑɲ		lúɔˑɲ-nì̤	
‘bone’	Frank (1999: 84)	cɔɣ	cɔ̱ɔ̱ɣ	cɔ̱ɔ̱ɣkä		cɔ̱ɔ̱ni̱	
	Current study	cɔ̤̀a̤ː	cɔ̤̄ˑw	cɔ̤̀ː-kɛ̤́		cɔ̤̄ˑw-ní̤	

Table 7.1: Comparison of data

To sum up, the differences in Table 7.1 reveal that the data of this study are quite different from Frank (1999). There are segmental differences, and the genitive and locative case form one category in the Ethiopian variety of Jikany Nuer. This might be unique to this specific variant of Nuer.

7.2.2 Suffix distribution

Table 7.2 below presents the suffix distributions found in this study. The suffix *-kɛ̤* is used for the oblique singular and *-ni̤* marks the plural. As has also been observed in Frank (1999), these two suffixes lose their onset consonant (*-n* and *-k*) following stems which end in liquids: /l/ and /r/. Both Gajaak and Gajiök speakers delete the /n/ in forms such as e.g., the oblique plural of *pàˑl-í̤* ‘rituals’ and *lɔ̤́ːr-ì̤* ‘Acacia Seyal tree’, and the forms **pàˑl-ní̤*, **lɔ̤́ːr-nì̤* are ungrammatical.

There is a dialect difference for liquid deletion among the speakers of this study. After liquids, Gajaak speakers do not delete the *-k* in *-kɛ̤*, they only delete *-n* in *-ni̤*, whereas Gajiök speakers delete both *-k* and *-n* after liquids and also after nasals. The difference for *-k* deletion is shown below in (152)–(153).[6] There is no indication that liquid deletion affects tone in this study.

Dialectal differences in *-k* deletion after liquids and nasals

(152) Gajiök

a. nɛ̤̀ˑn-ɛ̤́ mirror-OBL.SG

b. pâˑl-ɛ̤̀ ritual-OBL.SG

(153) Gajaak

a. nɛ̤̀ˑn-kɛ̤́ mirror-OBL.SG

b. pâˑl-kɛ̤̀ ritual-OBL.SG

[6] Because the data of this study come from Gajaak and Gajiök speakers, both forms are shown in the cited examples depending on which speakers the data come from.

When only considering the distribution of suffixes, there are five inflection classes. These classes capture which categories and classes of nouns get the singular suffix *-ke̤* and the plural suffix *-ni̤* in this study. The nominative singular does not have any suffixes and is considered the base form. The inflected form without suffixes undergoes stem-internal alternations. Table 7.2 shows the suffix distribution starting top-down: Class I has suffixes in all inflected forms; class II has suffixes only in the nominative and oblique plural; class III has suffixes in the singular and plural of the oblique case; class IV has suffixes only in the oblique plural form; and class V has no suffixes.

CL	NOM SG	OBL SG	NOM PL	OBL PL	Gloss	Total # of items
I	kè̤ːr	kè̤ˑr-ké̤	kè̤ˑr-í̤	kè̤ˑr-í̤	‘line’	28
	nè̤ˑn	nè̤ˑn-ké̤	nè̤ˑn-í̤	nè̤ˑn-í̤	‘mirror’	
II	bṳ́ˑk	bṳ́ɔ̤ːk	bṳ̀ɔ̤ːŋ-í̤	bṳ̀ɔ̤ːŋ-í̤	‘Nuer god’	5
	tɛ̂r	tɛ̂ˑr	tɛ̄ˑr-í̤	tɛ̄ˑr-í̤	‘conflict’	
III	wɔ̤́ˑk	wṳ́ˑk-è̤	wɔ̤́ːk	wɔ̤́ːk-nì̤	‘shoulder’	16
	tét	tét-kè̤	tét	tét-nì̤	‘hand’	
IV	kêːr	kè̤r	ké̤r	ké̤r-ì̤	‘calabash plant’	26
	dó̤ːr	dò̤ːr	dʊ̂ˑr	dʊ̂ˑr-ì̤	‘tribe’	
V	dɛ̂ˑl	dɛ̀e̤ːl	dé̤t	dé̤ːt	‘sheep/goat’	11
	jâŋ	jàːŋ	hɔ́ˑk	hɔ̤̀ːk	‘cow’	

Table 7.2: Proposal of inflection classes according to suffixation.

Generally, the stems do not undergo segmental changes of vowel quality or voice quality when a suffix attaches. In vowel quantity, most nouns keep the same length with and without the suffix. Exceptionally, a few nouns shorten their vowel length. There are also some peculiar cases which lengthen the stem in the plural oblique case. For example, the noun ‘Acacia Seyal tree’ has a mid-long vowel in the nominative plural, lɔ̤́ˑr. The vowel lengthens when a suffix attaches in the oblique plural lɔ̤́ːr-ì̤. The latter form has the same length as the nominative singular: lɔ̤́ːr.

Besides the five classes, I found one additional suffixal pattern. The noun *gàt* ‘child’ has no suffixes in the nominative and oblique plural, but it does have a suffix in the oblique singular: *gàt-kè̤*. For some speakers, this pattern was also found in the noun for *bá̤ˑr* ‘Anuak’. For example, Gajiök speakers use a suffix only in the oblique singular: *bé̤r-è̤*, whereas Gajaak speakers use no suffix. Since there is only the noun *gàt* which gets a suffix in the singular by all speakers, I do not treat this pattern as a separate class.

It should also be observed that the suffix *-ni̤* can be found in both the nominative plural and the oblique plural (class I–II) or only in oblique plurals. The opposite is not found; that is, no nouns have *-ni̤* in the nominative plural but not in the oblique plural. I claim that this is not a coincidence but a consequence of the serial derivation of inflection in Nuer, as will be shown in the analysis of chapter 9.

One similarity between this study and Frank (1999) is that suffixation is the productive form in nominal inflection. I also collected loanwords to check for productive patterns in tone and suffixation. Most come from English such as *ɟɛ̤̀k* 'jacket' and *bôk* 'book'. One is from Italian *bɛ̤̀nt̪ɛ̤̀lɔ́·n* (pantaloni) 'pants'. A few are from Arabic such *t̪úrɛ̀* 'picture' and *cúrâ·b* 'socks'.

Some examples are given below in Table 7.3. Not surprisingly, nearly all loanwords elicited for this study had suffixes in every inflected form and were stable nouns – see the next section for definitions. This corresponds to the results of Frank (1999) who referred to this class as the regular class. The exception was the noun *bôk* which lacks a suffix in the oblique singular form – see Appendix A for more examples.

STEM TYPE	NOM SG	OBL SG	NOM PL	OBL PL	Gloss
Stable	ɟɛ̤̀k	ɟɛ̤̀k-ɛ̤́	ɟɛ̤̀k-ní̤	ɟɛ̤̀k-ní̤	'jug'
	gálàm	gálàm-ɛ̤́	gá·làm-ní	gálàm-ní̤	'pen'
	bɛ̤̀nt̪ɛ̤̀lɔ́·n	bɛ̤̀nt̪ɛ̤̀lɔ̀·n-ɛ̤́	bɛ̤̀nt̪ɛ̤̀lɔ̀·n-ní̤	bɛ̤̀nt̪ɛ̤̀lɔ̀·n-ní̤	'pants'
	bôk	bòk	bōk-ní̤	bōk-ní̤	'book'

Table 7.3: Inflection of loanwords

7.2.3 Proposal for stem distinctions

I have shown in the previous section that the distribution of *-kɛ̤* and *-ni̤* is not really 'chaotic' compared to the studies by Frank (1999) and Baerman (2012). Still, these inflectional patterns would need five classes to account the suffix distribution. I propose three kinds of phonologically motivated stem distinctions which can account for the majority of these suffixation patterns so that classes are superfluous: stable, unstable, and hybrid stems. Stable and unstable stems were discussed in chapter 5, where I showed that they behave differently concerning the OCP-L repair 'H tone epenthesis'. I proposed that unstable stems are underspecified with a floating lexical tone, and stable stems are fully specified. It turns out that suffixation and H tone epenthesis affect these two stem types in a similar manner. Unstable stems behave uniformly as defective. In sequences of L tones, OCP-L violations are repaired by epenthesizing a H tone on them. This works the same in inflection. To foreshadow the next sections of this chapter, in number and case inflection, their lexical tone gets replaced by an inflectional tone. Stable stems, on the other hand, are generally immune to H tone epenthesis and let adjacent syllables get this H tone. In number and case inflection, they get a suffix instead of a floating tone on the stem.

In addition to stable and unstable stems, there is a third type of stem which comes out in inflection. Nouns with this stem have some similarities with stable stems and other similarities with unstable stems. Therefore, I name such nouns ‘hybrid stems’. On the one hand, they have some properties of stable stems in that they are immune to H tone epenthesis. Also, in case inflection, the singular nouns get a suffix instead of an inflectional tone on the stems. On the other hand, they are similar to unstable stems in the plural because they get overwritten by the H tonal tree instead of getting a suffix. The autosegmental structure of hybrid stems is shown further in chapter 9.

Table 7.4 provides an overview of the properties of the stems in relation to inflection and H tone epenthesis. Following this, Table 7.5 displays the stem categories and their relation to the suffix distribution of Table 7.2 above.

	SINGULAR		
	Oblique exponence		Target of H tone epenthesis
Stem type	Suffixation (-ke̤)	L tonal tree on stem	
Stable stems	✓	✗	✗
Hybrid stems	✓	✗	✗
Unstable stems	✗	✓	✓
	PLURAL		
	Nominative exponence		
	Suffixation (-ni̤)	H tonal tree on stem	
Stable stems	✓	✗	✗
Hybrid stems	✗	✓	✗

Table 7.4: Stem contrasts in inflection and H tone epenthesis. In the singular, there is a two-way contrast between stable and unstable nouns. Stable nouns contrast with hybrid nouns in plural exponence.

CL	NOM SG	OBL SG	NOM PL	OBL PL	
I	Ø	-ke̤	-ni̤	-ni̤	Stable stems
II	Ø	**Ø**	-ni̤	-ni̤	Stable stems
III	Ø	-ke̤	**Ø**	-ni̤	Hybrid stems
IV	Ø	**Ø**	**Ø**	-ni̤	Unstable stems
V	Ø	**Ø**	**Ø**	**Ø**	Unstable stems

Table 7.5: Classification for inflection classes based on suffix pattern and tone. The bolded marked ‘**Ø**’ indicates stem-internal modifications.

In the remainder of this chapter, I demonstrate that the plural has a H tone pattern and the oblique case a L tone pattern. I provide the generalizations for how the number and case exponents interact with the three stem categories proposed here.

7.3 Plural marking in Nuer

In section 7.1, I mentioned how number marking in Western Nilotic languages is especially complex. I argue that it is more simple in Nuer, in that the plurals are derived from the singular for suffixation and tone. In this sense, the plurals are inflected forms in Nuer. The basic and modified distinction in Nilotic can, however, help to understand some patterns and exceptions in Nuer. Section 7.3.1 below discusses some of the segmental subregularities of number marking and whether they relate to tone. In section 7.3.2, I show that there is consistency in the plural inflection concerning tone and suffix distribution.

7.3.1 Exponence and subregularities

Table 7.6 gives an overview of the different exponence of plural marking found in this study. Only stable stems exclusively use suffixes for marking the inflectional forms for case and number. For example, *nè̤ˑn* 'mirror' forms the plural by adding a suffix *nè̤ˑn-í̤*. Hybrid and unstable stems involve stem-internal modifications in the plural, as was also shown in Table 7.2 above.

Exponents	NOM SG	NOM PL	Gloss	Stem
No marking	tét	tét	'hand'	Hybrid
1 exponent				
Suffix	nè̤ˑn	nè̤ˑn-í̤	'mirror'	Stable
V length (1 mora: mid to long)	wɔ̤́ˑk	wɔ̤́ːk	'shoulder'	Hybrid
V length (2 moras: long to short)	kɔ̤́a̤ːk	kɔ̤́a̤k	'hole'	
V quality	wɐ̤́ˑn	wá̤ˑn	'thief'	Unstable
Tone	ɟó̤m	ɟò̤m	'jaw'	
Multiple exponents				
Monophthongization, tone, V shortening	rɛ̀ɐ̤ːt̪	rɛ́ˑt̪	'dryness'	Hybrid
Diphtongization, V lengthening	rɔ̤́ˑt̪	rɔ̤́a̤ːt̪	'armpit'	Unstable
Diphtongization, tone, V lengthening	lòɲ	lûɔˑɲ	'lion'	
V quality, phonation, tone	lɔ̂ˑc	ló̤ˑc	'heart'	
V quality, phonation, V shortening, tone	kêːr	ké̤r	'calabash plant'	
V quality, phonation, V shortening, tone	dó̤ːr	dʊ̂ˑr	'tribe'	
Suppletion	jâŋ	hɔ́ˑk	'cow'	Unstable
	cí̤e̤k	mɐ̤̀ˑn	'woman'	

Table 7.6: Examples of exponents in number marking

Furthermore, in the plural, hybrid and unstable nouns undergo stem-internal modifications of one or more exponents. Most frequently, there is multiple exponence. For example, the noun *dǫ̤́ːr* ‘tribe’ in Table 7.6 above changes four stem properties in the plural formation. A few nouns mark a category with only one exponent. For example *kɔ̤́a̤ːk* ‘hole’ which changes vowel length in the plural. The noun *tét* ‘hand/hands’ does not change at all in the singular and plural form – see the end of section 2.3 for more on this noun.

One difference between Eastern Jikany and other Nuer dialects of the West lies in coda consonant mutation. While this is an active part of inflection in Western Nuer dialects, it is rarely part of the inflection in Eastern Jikany. Only a few nouns have a coda alternation between the singular and plural forms. These are shown in Table 7.7 below. The coda changes in these nouns are considered a lexicalized phenomenon.

NOM SG	NOM PL	Gloss
ɟàˑt̪	ɟɛ́ˑn	‘tree’
dɛ̂ˑl	dé̤t	‘sheep/goat’
pàˑj	pɐ̤́ˑt̪	‘moon’

Table 7.7: Attested nouns with coda consonant alternation.

Some examples of the bidirectional pattern in number formation described in section 7.1 can be seen below. In (154), the singular form has a mid-long vowel (*wɔ̤́ˑk*) which gets lengthened in the plural (*wɔ̤́ːk*). This is the most frequent derivation in this study. The opposite is shown in (155) where the plural form has a short vowel *kɔ̤́a̤k* which gets lengthened in the singular form *kɔ̤́a̤ːk*.

(154) Vowel lengthening

a. wɔ̤́ˑk
‘shoulder’

b. wɔ̤́ːk
‘shoulders’

(155) Vowel shortening

a. kɔ̤́a̤ːk
‘hole’

b. kɔ̤́a̤k
‘holes’

A similar bidirectional process can be observed with vowel quality. In (156), the singular has the vowel /ɐ̤/ which lowers to /a̤/ in the plural. The opposite pattern is only found in vowel height where the singular has the modal vowel /a/ which changes to the breathy /ɐ̤/ in plurals (157). In the vowel grade system of Reid (2019), /ɐ̤/ is considered a basic vowel (grade 2A) and /a̤/ a modified vowel (grade 2B). Following these grades, the singular form *wɐ̤̂ˑn* in (156) would be the basic one, while the singular form ɲâˑŋ in (157) would be the modified one, which has lost its breathyness in this dialect. Regardless of these vowel alternations, both the basic and modified plural forms have a H tone which I claim marks the plural in the next section.

(156) Vowel quality: e̤ → a̤
a. wé̤·n
'thief'
b. wá̤·n
'thieves'

(157) Vowel quality: a → e̤
a. ɲâ·ŋ
'crocodile'
b. ɲé̤·ŋ
'crocodiles'

The vowel alternation a → e̤ seems to be more frequent in this study indicating that this dialect has different vowel alterations than Lɔu Nuer. Another example is the noun 'eye' where the singular has the modal /a/ instead of the expected a̤ (158).

(158) a. wàŋ
'eye'
b. wé̤·ŋ
'eyes'

It was mentioned in section 7.1 that contour tones in Dinka often arise on complex stems with long vowels, breathy voice and/or grade 2-3 vowels. This is not the case in this study. In fact, I argued in chapter 2 that HL tones are lexical and independent of vowel length because HL tones appear unrestricted on singular stems and do not depend on vowel length or vowel quality. More data support this claim. In (159a)–(159b), the HL tones do not correlate with moraic length because short vowels (either the simple stems, the modified stems, or both) have a HL tone. In (159c), the stem could be considered basic because it has a monophthong. It has a HL tone while the modified stem with a diphthong has a L tone.

(159) Singular basic stems with HL tone
a. kôt̪ 'god' Modified PL stem: kṳ́t̪
b. gɔ̂·l 'fire' Modified PL stem: gɔ̂al
c. rɔ̂ːm 'sheep' Modified SG stem: rɔ̀aːm

Following the generalizations of Storch (2005), mentioned in section 7.1.2, and the vowel grade system of Reid (2019), the examples in (159b)–(159c) show that basic stems can have HL tones. The nouns *gɔ̂·l* and *rɔ̂ːm* can be considered basic stems because they have a monophthong which changes to diphthongs in the plural (modified stems). These examples indicate that HL tones appear independently of the vowel quality and stem complexity. There is a clear pattern in this study for plural stems to be breathy and H-toned. According to Storch (2005: 198–199), a vowel change from modal to breathy indicates a morphologically modified stem vowel, and this study shows many singular HL tones which become H in the plural. Phonation correlates with this alternation in that most singular nouns have a modal vowel, and most of the plural nouns have a breathy vowel. Some examples of this are shown in (160)–(162) below. For example, the singular form of 'heart' is a stem with a modal vowel and a HL tone (160a). In the plural, the vowel is closed and breathy and gets a H tone (160b).

(160) a. lɔ̂·c
'heart'
b. lɔ̤́·c
'hearts'

(161) a. kê:r
'calabash plant'
b. kḛ́r
'calabash plants'

(162) a. kôt̪
'god'
b. kṳ́t̪
'gods'

The breathy voice with H tones in the plural also falls under another subregularity of collective nouns. As was mentioned for Dinka in section 7.1, collective nouns which are singularized get a HL tone. The corresponding collective noun has a H or L level tone. The same can be observed for Nuer below in (163)–(164).

HL tones on singularized nouns from collective nouns

(163) 'sheep/goat'
a. dḛ́t *collective*
b. dɛ̂·l *singulative*

(164) 'milk'
a. cɛ̤́·k *collective*
b. câ·k *singulative*

The majority of the data has singular HL forms with modal vowels and plural H forms with breathy vowels. A couple of nouns show the opposite pattern with a singular breathy vowel with a H tone and a plural modal vowel with a HL tone; e.g., the H-toned singular *d̪ɔ̤́:l* in (165).

(165) a. d̪ɔ̤́:l 'boy'
b. d̪ɔ̂:l 'boys'

Regardless of the amount of multiple exponence which stems are subject to in number inflection, I claim that tone alternations happen independently of vowel grades or notions of stem complexity. The parameters which are sufficient for deriving inflectional tone and suffixation patterns are the stem types stable, unstable, and hybrid, and the number and case exponents which I will present in the next sections.

7.3.2 H tone patterns in plural

As Table 7.8 showed above, stable stems form the plural by suffixing -*n̤i̤*. Hybrid and unstable stems, on the other hand, form the plural by stem-internal modifications (vowel lengthening or shortening, change in vowel quality, or tone alternation). I argue that when considering the tones, the singular nominative stems do not have predictable tone patterns because their stems have lexical tones. Furthermore, the plural can be derived from the singular. In comparison to singular nouns, the plural forms are more predictable because they involve inflectional tone; a H tonal tree marking the plural (a H tone associated to a tonal root node).

The tones of the stable nouns are predominantly L-H regardless of the tone on the singular stems. That is, a singular stem with either a H, L, or HL tone will in the majority of the cases form a L plural stem with the H-toned suffix *-ni̤*. This is shown in Table 7.8 below. L-toned singular stems become L-H in the plural, singular stems with a HL tone get simplified to L when the H suffix attaches, and H tone singular stems become L-H. Loanwords also have these tone patterns. Monosyllabic loanwords have L-H tones as well. Bisyllabic loanwords end in a L tone on the stem and take a H suffix, e.g. *gálàm-ní* 'pens' – see Table 7.3. From this it can be concluded that the tendency is a L-H pattern in nominative plurals. In addition, three nouns have a M tone which stays M. However, this pattern has some variation among speakers. For example, in the plural form of the noun *gwák* 'dry grass', speakers vary between a M-H *gwāk-ní̤* and a L-H *gwàk-ní̤* 'dry grass'.

Stem Tone	NOM SG	NOM PL	Gloss
L→L-H	wàt	wàt-ní̤	'relative'
	tɔ̤̀t	tɔ̤̀t-ní̤	'summer'
	kḛ̀ːr	kḛ̀ˑr-í̤	'line'
	nḛ̀ˑn	nḛ̀ˑn-í̤	'mirror'
	gwàk	gwàk-ní̤	'fox'
H→L-H	gá̤ˑc	gà̤ˑc-ní̤	'belt'
	bṳ́ˑk	bṳ̀ɔ̤ːŋ-í̤	'Nuer god'
HL→L-H	pâˑl	pàˑl-í̤	'ritual'
	kɔ̂m	kɔ̀m-ní̤	'chair'
	kôˑt̪	kòˑt̪-ní̤	'cup'
	dêˑc	dèˑj-ní̤	'soldier'
	tɛ̂ːr	tɛ̀ːr-í̤	'September'
M→M-H	twɔ̤̄ˑt	twɔ̤̄ˑt-ní̤	'wild goose'
	tɛ̂r	tɛ̄ˑr-í̤	'conflict'
	gɔ̂ːk	gɔ̄aˑk-ní̤	'monkey'

Table 7.8: Plural formation of stable nouns in nominative: suffixes of -ní̤

The hybrid and unstable nouns form the plural by stem-internal modifications. The plural stems appear with mainly a H or a HL tone regardless of the tone of the singular stem and regardless of the vowel length, grade or voice quality (see the appendix A). There are overall more H tones in the plural compared to the singular stems. For the singulars, there is no consistent tone pattern to recognize and they are considered the base form with a lexical tone. Table 7.9 shows singular stems of H, L, or HL tones which become H in the plural. It can be observed that plural forms have a breathy vowel. I argue that this is a segmental feature of the plural stems.

SG stem	PL stem	Gloss
HL tone	H tone	
kôt̪	kṳ́t̪	‘god’
lɔ̂ˑc	ló̤ˑc	‘heart’
kâl	kɛ̤́ˑl	‘fence’
câˑk	cɛ̤́ˑk	‘milk’
lwâˑk	lwé̤ːk	‘cattle hut’
lâp	lɛ̤́p	‘placenta’
dɛ̂ˑl	dé̤t	‘sheep/goat’
H tone	H tone	
tét	tét	‘hand’
wɛ̤́ˑn	wá̤ˑn	‘thief’
bṳ́ˑl	bṳ́ɔ̤ˑl	‘drum’
wɔ̤́ˑk	wɔ̤́ːk	‘shoulder’
rɔ̤́ˑt̪	rɔ̤́a̤ːt̪	‘armpit’
L tone	H tone	
pàˑj	pɛ̤́ˑt̪	‘moon’
rɛ̀ɐ̤ːt̪	rɛ́ˑt̪	‘dryness’
lɛ̤̀k	lá̤ːk	‘dream’
kè̤ˑn	ké̤ˑn	‘type of bird’
ɟɔ̀k	ɟóˑk	‘back’

Table 7.9: Plural formation with unstable and hybrid stems: H tone on plural stems

The few plural nouns which do have a L tone are given below in (167) with the singular forms in (166). The noun *wɛ̤̀t̪* ‘warrior’ has a short vowel which is lengthened in the singular. Although I argue that stem complexity is not relevant for the majority of tone patterns, it might explain some of the exceptions. If one considers the basic/modified division of stems, the L-toned plural has a basic form. In this line of thought, the fact that it is a basic plural might explain why it is exceptionally L-toned.

For the nouns *ɟɔ̤̀m* ‘jaws’, and *ɟà̤ːl* ‘visitors’, their L tone cannot be due to their stem complexity because the singular and plural stems are either segmentally the same, as for ‘jaw’, or the plural is the modified stem, as for ‘visitor’. However, it should be noted that for *ɟɔ̤̀m*, this form is only used by the Gajiaak speaker and for the Gajiök speaker it is H-toned, *ɡɛ̤́ˑm* ‘jaws’. Another interesting observation is that both *ɟɔ̤̀m* and *ɟà̤ːl* get a H tone in the plural form of oblique case; *ɟɔ̤́m-nɪ̤̀* jaw\PL-OBL.PL – *ɟá̤ːl-ɪ̤́* visitor\PL-OBL.PL. Thus, the plural H tone does manifest itself on the stem in these forms.

(166)	Singular H stems	(167)	Plural L stems	Gloss
	a. wɛ̤́ːt̪		a. wɛ̤̀t̪	‘warrior’
	b. ɟɔ̤́m		b. ɟɔ̤̀m	‘jaw’
	c. ɟá̤ˑl		c. ɟà̤ːl	‘visitor’

7.3.3 Interim summary

This section has discussed plural formation in Nuer nouns and their tonal patterns. I argued that plurals have a H tone pattern in the nominative forms. Stable stems get a suffix with a H tone. Hybrid and unstable nouns are monosyllabic in the plural and get predominantly a H or HL tone. A small group which mainly consists of plural simple stems have a L tone and are treated as an exception. Thus, hybrid and unstable stems get a replacive tone in the plural which appears regardless of the tone of the singular stems. That is, while singular stems have either H, HL, or L stems, plural stems tend to have H or HL tones independently from their underlying tone. The singular stems are therefore assumed to have a lexical tone. These generalizations are given in (168). The next section presents evidence for a L tone pattern in the oblique case.

(168) Plural formation in Nuer:

a. Exponents: surface H tone; segmental suffix *-ni̤*
b. The exponents target stems differently:
   (i) *-ní̤* attaches to stable stems
   (ii) H(L) tones surface on unstable and hybrid stems

7.4 Oblique case

Tone also plays a prominent role in the oblique case in Nuer. While section 7.3 showed that H and HL tones are prevalent in the plural, this section shows that L tones are tonal exponents of the oblique case. I argue that a L tone or a L-toned suffix marks the oblique case, i.e., nouns in genitive and locative constructions – see 1.1.3 for an overview on case constructions in Nuer. The way the exponence manifests itself depends on the stem type.

Apart from Nuer, it has also been shown that tone is an exponent of case in Dinka; Trommer (2011) argues for a tonal polarity pattern in this language between the singular and the plural forms which arises due to a floating rising tone. Either the H or L component of the rising tone links to the stem and overwrites its stem tone.

For Nuer, I argue that a L tonal tree marks the oblique case. While the L tonal tree applies globally to all inflection classes, it manifests itself differently by targeting either the segmental suffixes or the stems alone. The stem distinctions proposed in 7.4 make it easy to determine this difference in exponence. Recall from chapter 5 that stable nouns have a specified tone in the lexicon which is linked to the stem while unstable stems have a floating lexical tone. The evidence for this was that H tone epenthesis cannot overwrite lexical L tones when OCP-L is violated, but it can overwrite unstable stems. This difference between the stems is consistent in case inflection. The general pattern is that for the oblique case in the singular, stable stems get a suffix, whereas unstable stems surface with a L tone on the stem. Section 7.4.1 presents the monosyllabic forms of singular unstable stems in the oblique case, and section 7.4.2 presents the suffix distribution in stable and hybrid singular stems which get the suffix -*kɛ̤*. In the plural, hybrid and unstable stems get the L-tones suffix -*nì̤* (except for class V), whereas stable stems do not change from the nominative. Exceptions to these patterns are discussed in section 7.4.3.

7.4.1 Unstable nouns with monosyllabic forms

Monosyllabic forms in the oblique case appear with unstable stems and involve stem-internal modifications. Recall that unstable nouns were the tones which got overwritten by H tone epenthesis. This is possible because their lexical tone is floating in the input – see chapter 5. In inflection, they also behave 'unstable' by getting inflectional tones on their stems instead of a suffix. In the oblique case singular, unstable stems have a consistent L tone pattern.

Case marking in Nuer is similar to plural marking by having multiple exponence involving vowel alternations. To give some examples, there are vowel alternations such as diphthongization from the nominative to oblique case in the singular: *rɔ̤́ˑt̪* → *rɔ̤̀a̤ːt̪* 'armpit' or *lɔ̂ˑc* → *lɔ̀aːc* 'heart', and many alternations involve vowel quality and length: *d̪ó̤ːl* → *d̪ʊ̀l* 'boy', *wɛ̤́ˑn* → *wà̤ˑn* 'thief'. Below, an alternation is shown in the unstable nouns *rṳ́p* 'forest' and *dwéˑl* 'house'. The nouns have a H tone in the nominative case (169). In (170), they appear with a L tone and vowel lengthening. Here, the meaning has changed to locative referring to the location of the forest or the house.[7]

(169) Nominative

a. têˑ rṳ́p
COP forest
'(S)he has a forest.'

b. têˑ dwéˑl
have.3.SG house
'(S)he has a house.'

(170) Oblique case

a. têˑ rṳ̀ːp
COP forest.OBL
'(S)he is in a forest.'

b. têˑ dwɛ̤̀ːl
have.3.SG house.OBL
'(S)he is in the house.'

The surface L tone observed in (170) shows up consistently on unstable stems in the singular forms of the oblique case. As with plural marking, I claim that the segmental changes which

[7] In the construction with *têˑ*, the nouns with the locative meaning usually takes the same segmental form of the genitive or a locative construction with a preposition. This is the case for, e.g., 'house' where the oblique form is also *dwɛ̤̀ːl*. Some nouns, however, take the segmental form of the nominative but with an oblique L tone. For example, *rṳ̀ːp* has the nominative form *rṳ́p* and the oblique form *rṳ́ɔ̤ːp*.

unstable nouns undergo are not a necessary parameter in the analysis I propose for tone. Tone appears to be the most consistent exponent for case in that it can be traced to a L tone independently from the segmental changes on stems. That is, monosyllabic oblique nouns get a surface L tone in the oblique case, regardless of the vowel alternations. First, the L tone also appears when there are no vowel alternations as in (171)–(172).

(171) ‘fence’

a. kâl NOM
b. kàl OBL

(172) ‘god’

a. kôt̪ NOM
b. kòt̪ OBL

Second, the surface L tone in the oblique case is found independently from changes in vowel length. It appears on vowels which are lengthened in the oblique case as in (173)–(174). However, the L tone also appears when the oblique singular form is shorter than the nominative form (175)–(176).

(173) ‘lake’

a. bâˑr NOM.SG
b. bàːr OBL.SG

(174) ‘drum’

a. bṳ́ˑl NOM.SG
b. bṳ̀ɔ̤ːl OBL.SG

(175) ‘calabash plant’

a. kêːr NOM.SG
b. kè̤r OBL.SG

(176) ‘boy’

a. d̪ó̤ːl NOM.SG
b. d̪ʊ̀l OBL.SG

More examples of the L tone pattern on unstable nouns are given in Table 7.10. Nearly all unstable stems surface with a L tone in the oblique singular forms.

Nominative	**Oblique case**	Gloss
H	**L**	
rɔ̤́ˑt̪	rɔ̤̀a̤ːt̪	‘armpit’
d̪ó̤ːl	d̪ʊ̀l	‘boy’
dó̤ːr	dò̤ːr	‘tribe’
HL	**L**	
lɔ̂ˑc	lɔ̀aːc	‘heart’
kôt̪	kòt̪	‘god’
bôk	bòk	‘book’
dɛ̂ˑl	dɛ̀ɐ̤ːl	‘sheep’
L	**L**	
lòɲ	lùɔˑɲ	‘lion’
tɔ̤̀t	tɔ̤̀a̤t	‘summer’

Table 7.10: L tone pattern on unstable stems

The L-toned monosyllabic forms of unstable nouns in the oblique case show no difference whether they are pronounced in a genitive or locative construction which is in isolation or in a sentence. The L tone on the stem appears also when they are in a sentence-medial position. This is shown in the examples in (177a) and (178a) where the nouns have a HL tone in the nominative form which becomes L in the oblique form (177b) and (178b). The same goes for the noun for 'tribe' which has a H tone in the nominative (179a) which becomes L-toned in the oblique form (179b). Nouns with L tones in the nominative such as (180a) keep their L tone in the oblique form (180b).

Lexical H or HL tones

(177) HL → L

a. hē̤n c-é̤ lɔ̂ˑc nɛ̀ˑn
1SG PFV-1SG heart see
'I have seen the heart.'

b. hē̤n c-é̤ ríɛˑm lɔ̀aːc nɛ̂ˑn
1SG PFV-1SG blood heart\OBL see
'I have seen the blood of the heart.'

(178) HL → L

a. hē̤n c-é̤ bôk nɛ̀ˑn
1SG PFV-1SG book see
'I have seen the book.'

b. hē̤n c-é̤ pé̤c bòk nɛ̂ˑn
1SG PFV-1SG page book\OBL see
'I have seen the page of the book.'

(179) H → L

a. hē̤n c-é̤ dó̤ːr nɛ̀ˑn
1SG PFV-1SG tribe see
'I have seen the tribe.'

b. hē̤n c-é̤ kwáˑr dò̤ːr nɛ̂ˑn
1SG PFV-1SG king tribe\OBL see
'I have seen the king of the tribe.'

Lexical L tones

(180) L (no change)

a. hē̤n c-é̤ lòɲ nɛ̂ˑn
1SG PFV-1SG lion see
'I have seen the lion.'

b. hē̤n c-é̤ dɛ̂ːj lùɔˑɲ nɛ̂ˑn
1SG PFV-1SG puppy lion\OBL see
'I have seen the puppy of the lion.'

7.4.2 Suffix forms

Another way of marking the oblique case is by adding a suffix to the stem. In the singular, this happens to stable and hybrid stems which get the suffix *-kɐ̤* in the oblique case. The tone of this suffix is L if the stem has a HL or a H tone. Examples are given in Table 7.11.

Stem	Nom	Tone	Oblique	Tone	Gloss
Hybrid	wɔ̤́ˑk	H	wṵ́ˑk-è̤	H-**L**	'shoulder'
	tét	H	tét-kè̤	H-**L**	'hand'
	kɔ̤́a̤ˑk	H	kɔ̤́ˑk-è̤	H-**L**	'hole'
	lɔ̤́ːr	H	lṵ́ˑr-è̤	H-**L**	'Acacia Seyal tree'
	tɔ̂ˑk	HL	tôˑk-è̤	HL-**L**	'gourd'
Stable	dêˑc	HL	dêˑj-kè̤	HL-**L**	'soldier'
	dɛ̂ˑp	HL	dɛ̂ˑp-kè̤	H-**L**	'butter'

Table 7.11: Oblique case singular marking with stable and hybrid stems

Speakers show some variation in the realization of HL-tones on the stems when a suffix is added. For example, *dêc-è̤* soldier-OBL.SG is mostly realized with a HL tone on the stem *dɛ̂ˑp-è̤*, but in fast speech, it can be realized with a H or M tone *dɛ́ˑp-è̤* or *dɛ̄ˑp-è̤*. The noun *tôˑk-è̤* gourd-OBL-SG is realized invariably as HL-L.

Section 7.3.2 showed that plural stable stems get the suffix *-ni̤* in the nominative. With the exception of some of the unstable stems – see section 7.4.3, all stem types get the suffix *-ni̤* in the oblique plural forms. This suffix is L-toned for hybrid and unstable stems as shown in Table 7.12. Regarding the stem tones, the majority of the stem tones do not alter from nominative to oblique when they get a suffix. That is, a HL stem retains a HL tone when the L-toned *-ni̤* is added.

Stem	NOM PL	OBL PL	Gloss
Hybrid	wɔ̤́ːk	wɔ̤́ːk-nì̤	'shoulder'
	tôːk	tôːk-nì̤	'guord'
	tét	tét-nì̤	'hand'
Unstable	dʊ̂ˑr	dʊ̂ˑr-ì̤	'tribe'
	bṵ́ɔ̤ˑl	bṵ́ɔ̤ˑl-ì̤	'drum'
	ké̤r	ké̤r-ì̤	'calabash plant'

Table 7.12: L-toned suffix in oblique plural with hybrid and unstable stems

I claim that the L tone which appears on unstable stems is the same which appears on suffixes. I propose that the suffix -(k)e̤ marks the oblique case singular and is toneless. The suffix *-(n)i̤* marks plural and is also toneless (181).

(181) Tonal and suffixal exponence of case in Nuer (preliminary)

i. L tonal tree$_{[\text{OBLIQUE CASE}]}$
ii. -(k)e̤$_{[\text{OBLIQUE CASE: SG}]}$
iii. -(n)i̤$_{[\text{PL}]}$

Following the assumption that a L tonal tree marks the oblique case and suffixes are toneless, there is a tone pattern in stable stems which is unexpected. Recall from section 7.3.2 that they get a H tone on *-ni̤*. The stable stems in the oblique plural surface with a H-toned *-(n)í̤* and do not change from the nominative plural. Thus, the nominative and oblique forms are identical for these nouns as shown in Table 7.13.

STEM	NOM PL OBL PL	Gloss
Stable	kè̤·r-í̤	'line'
	nè̤·n-í̤	'mirror'
	dè·j-ní̤	'soldier'
	twɔ̤̄·t-ní̤	'wild goose'
	gwàk-ní̤	'fox'
	pà·l-í̤	'ritual'
	kò·t̪-ní̤	'cup'

Table 7.13: Stable stems in plural nominative and oblique case

This H tone pattern on stable stems might appear to be an exception to the L tone pattern in the oblique case. One possible account of this pattern would be that *-ni̤* has an underlying tone, and that there are two *-ni̤* suffixes: one H-toned and another which is either toneless or L-toned. Instead, as I elaborate in chapter 9, I claim there is only one *-ni̤* which is toneless. Either the plural H tonal tree links to a noun early and goes on its stem, as for hybrid and unstable stems. For these nouns, *-ni̤* is toneless and gets a L tone in the oblique case. For stable nouns, the plural H tonal tree goes on the suffix *-ni̤* so that in the oblique case, it is too late for the suffix to link to the L tonal tree.

7.4.3 Exceptional patterns

Two groups of nouns have a different pattern from the descriptions in 7.4.1–7.4.2. The first group concerns four stable stems which fail to get a suffix in the singular forms of the oblique case. Two of these nouns have a L tone in the oblique case. The L-toned noun *tɔ̤̀t* 'summer' stays L in the oblique case *tɔ̤̀a̤t*. The HL-toned noun *gɔ̂ːk* gets a L tone in the oblique singular form *gɔ̀a·k*. Two nouns do not change. The H-toned *bṳ́·k* 'Nuer god' stays H in the singular oblique form *bṳ́ɔ̤ːk*, and the HL-toned noun *tɛ̂r* retains a HL tone *tɛ̂·r*.

SG	SG.OBL	PL NOM – PL OBL	Gloss
bṳ́ˑk	bṳ́ɔ̤ːk	bṳ̀ɔ̤ːŋ-ḭ́	'Nuer god'
tɛ̂r	tɛ̂ˑr	tɛ̄ˑr-ḭ́	'conflict'
tɔ̤̀t	tɔ̤̀a̤t	tɔ̤̀t-nḭ́	'summer'
gɔ̂ːk	gɔ̀aˑk	gɔ̄aˑk-nḭ́	'monkey'

Table 7.14: Exceptional patterns of stable singular stems in the oblique case

The second group of exceptional nouns concerns unstable stems. They stay monosyllabic in the oblique plural failing to take the suffix -*nḭ*. They have either a H, L, or HL stem tone. Thus, they have an irregular pattern compared to the other plural nouns which get a L-toned suffix in the oblique case. The singular forms of these nouns behave as expected by taking a L tone on the stem in the oblique case. All five nouns show different tone patterns from the plural stem in nominative to the plural stem in the oblique: H → H, HL → HL, and L → HL – see Table 7.15 below. The tone of the singular forms is not a predictor to these irregular patterns. It should be noted that the frequency of these nouns is very low compared to the other noun classes. The two groups of exceptional nouns will be further discussed in section 9.7.

SG	PL	PL OBL	Gloss
dɛ̂ˑl	dḛ́t	dḛ́ːt	'sheep/goat'
ràːn	nâːt̪	↓nât̪	'person'/'Nuer'
jâŋ	hɔ́ˑk	hɔ̤̀ːk	'cow'
cí̤e̤k	mɛ̤̀ˑn	mɛ̤́ːn	'woman'
kwɛ̤́n	kwàn	kwâˑn	'food'

Table 7.15: Irregular tone patterns of unstable stems in the oblique case plural

7.4.4 Interim summary

This section showed a L tone pattern in the oblique case which manifests itself differently depending on whether the stems are stable, unstable, or hybrid. Singular stable and hybrid stems form the oblique case by adding -*kɘ̤* with a L tone. Unstable stems remain monosyllabic and surface with a L tone which replaces their lexical tone (H, L, or HL). As I showed in chapter 5, these nouns have a floating lexical tone which shows up in the nominative case. This tonal defectiveness of having a floating tone, therefore, relates their non-concatenative formation in inflection. In the plural, unstable and hybrid stems add -*nḭ* which surfaces with a L tone. Stable nouns fail to surface with a L tone in the oblique case and appear with a H tone on -*nḭ* just as in the nominative plural. I proposed that this suffix, just as -*kɘ̤*, are nevertheless both toneless. This assumption can capture the fact that the inflectional L tone, which is a L tonal tree, links to either the stem of unstable singular nouns or to suffixes. It also permits an analysis where there is only one *-ṇi̤* as opposed to having a H-toned *-ṇi̤* and a L-toned *-ṇi̤* which are separately specified in the lexicon. I claim that its H or L tone depends on *when* it attaches to the stem. In the serial analysis of chapter 9, I propose that the nominative is derived earlier than the oblique case. The H tonal tree in plural associates first. In the oblique case, it is 'too late' for stable plural stems to link to a L tonal tree, and only hybrid and unstable stems can get this tonal tree.

The L tone pattern in the oblique case creates sequences of adjacent L tones. In the next section, I discuss how this violates the OCP-L, and how H tone epenthesis targets nominal stems differently.

7.5 Case marking with OCP-L repairs

The ban on adjacent L tones in Nuer, OCP-L, becomes increasingly fascinating in the oblique case. Chapter 5 revealed that the OCP-L constraint is active at the phrase level in the nominative case. To avoid L sequences, a H tone is inserted in a suffix position, as defined in (69). The ban on adjacent identical tones is a constraint in OT (see Leben 1973, 1978; McCarthy 1986; Myers 1997). In chapter 9, this will be proposed as a high-ranked constraint in Nuer.

Chapter 5 established that H tone epenthesis targets syllables differently depending on whether they are stems with floating tones, such as unstable nouns, or lexically specified tones, such as stable nouns. These layers of tonal defectiveness explained how H tone epenthesis targets syllables of unstable stems, since they are not linked to a tone in the input, but cannot link to stable stems because they are already specified for tone.

In this section, I show that OCP-L is also active in the oblique case as it interacts with inflectional morphology and lexical tone. Just as in the nominative case, polarity patterns appear between stems and suffixes and between words at the phrase level. When underlying L tones are present in the input, the output is repaired by H tone epenthesis. Also in the oblique case, H tone epenthesis works as a diagnostic for the nature of the stems regarding their tonal structure and provide independent evidence for the stem distinctions used in inflection. In the previous section, I showed how stable nouns take a suffix while unstable nouns remain monosyllabic and are subject to L tone overwriting. Similarly to grammatical tone, H tone epenthesis targets different stems depending on whether they are stable (suffixable in the oblique case) or whether they are unstable (non-suffixable in the oblique case). That is, H tone epenthesis overwrites unstable stems but not stable stems. It is striking how the stable – unstable classification falls naturally out of the grammatical component in Nuer in the oblique case as well as in the phonological component with OCP-L.

7.5.1 Stems and affixes

Starting at the smallest level, H tone epenthesis targets inflectional suffixes. The suffixes *-ke̤* and *-ni̤* behave as toneless in Nuer because their tone depends on their surrounding environment. As was already shown in section 7.4.2, the suffix *-ke̤* is added in the oblique case to stable singular stems. In this case, they get a L tone if the stem has a H tone (e.g., wɔ̤́ˑk → *wṳ́ˑk-è̤* 'shoulder') or a HL tone (e.g., tɔ̂ˑk → tôˑk-è̤ 'gourd'). I claimed that this L tone pattern results from a L tonal tree marking the oblique case. If the stem has a L tone, however, this would create a L-L sequence violating the OCP-L. This sequence is not found with inflectional suffixes. Instead, the suffix gets a H tone with L stems as shown in Table 7.16.

Stem	Nom	Tone	Oblique	Tone	Gloss
H/HL tone stems → Oblique L tone on *-ke̤*					
Hybrid	wɔ̤́ˑk	H	wṳ́ˑk-è̤	H-L	'shoulder'
	tét	H	tét-kè̤	H-L	'hand'
	tɔ̂ˑk	HL	tôˑk-è̤	HL-L	'gourd'
	L tone stems → H tone epenthesis on *-ke̤*				
Stable	gwák	H	gwàk-é̤	L-H	'dry grass'
	gwàk	L	gwàk-é̤	L-H	'fox'
	nè̤ˑn	L	nè̤ˑn-ké̤	L-H	'mirror'
	kè̤ːr	L	kè̤ˑr-é̤	L-H	'line'
Hybrid	cɔ̤̀a̤	L	cɔ̤̀ː-ké̤	L-H	'bone'
	rɛ̀e̤ˑt̪	L	rɛ̀ːt̪-ké̤	L-H	'dryness'
	lè̤k	L	lè̤k-é̤	L-H	'dream'

Table 7.16: Polar pattern with singular suffixes

As was observed in chapter 5, HL tones do not trigger OCP-L violations with surrounding L tones. Note that plural monosyllabic nouns have mostly a H or HL tone at the stem and do not violate OCP-L. The proposal of the L tonal tree and H tone epenthesis captures most of the data in this study. There are only three exceptions found in total where nouns have a H-toned suffix and are neither stable nouns nor have a L tone on the stem. Two of these stems have a M tone and take a H-toned *-ni̤* as shown in (182)–(184) – see also (166)–(167) in section 7.3.2. Stems with M tones will be discussed in chapter 10.

Exceptions: plural oblique with H-toned *ní̤*

(182)	‘visitor’	(183)	‘boy’	(184)	‘bone’
	a. ɟà̤ːl NOM\PL		a. d̪ɔ̂ːl NOM\PL		a. cɔ̤̄ˑw NOM\PL
	b. ɟá̤ːl-í̤ OBL-PL		b. d̪ɔ̄ːl-í̤ OBL-PL		b. cɔ̤̄ˑw-ní̤ OBL-PL

7.5.2 Possessor markers

While the inflectional suffixes behave as toneless by getting either L or H tones depending on the tone of the stem, possessive markers behave as tonally specified. That is, they do not change tone depending on the stem, and L-tone possessive markers are not targeted by H tone epenthesis. In possessive constructions, the third person singular and plural markers appear with a L tone: SG *-dɛ̀* and PL *-kɛ̀*.[8] In comparison to the *-kɐ̤* and *-ni̤* suffixes, the possessive markers behave as if they have an underlying L tone because they do not alter their L tones when they combine with a L-toned stem. Again stable, hybrid, and unstable stems behave differently with these L-toned possessive markers. Stable and hybrid stems remain L-toned, whereas unstable stems raise their tone.

Observe the contrast of the examples below. When a L-toned possessive marker is added, stable stems retain their L tone with the possessive markers creating L-L patterns (185). Unstable stems, on the other hand, are subject to H tone epenthesis when combined with the L-toned possessive markers. In (186), the noun for ‘lion’ appears with a L tone when there are no adjacent L tones *lòɲ* – see also section 5.1. With the possessive marker, it gets a downstepped H tone. The same change is found on ‘person’ *raːn*. Also unstable plural nouns, which exceptionally have a L tone – see (166), are subject to H tone epenthesis (186c).

(185) Stable stems: L-L pattern

a. kè̤ːr-ɛ̀ /kè̤ːr/
line-POSS.SG:3SG
‘her/his line.’

b. nè̤ˑn-dɛ̀ /nè̤ˑn/
mirror-POSS.SG:3SG
‘her/his mirror’

c. gwàk-dɛ̀ /gwàk/
fox-POSS.SG:3SG
‘her/his fox’

(186) Unstable stems: /L/ → ꜜH

a. ꜜlóɲ-dɛ̀ /ᴸloɲ/
lion-POSS.SG:3SG
‘her/his lion’

b. ꜜráːn-dɛ̀ /ᴸraːn/
person-POSS.SG:3SG
‘her/his person’

c. ꜜɟó̤m-kɛ̀ /ᴸɟo̤m/
jaw\PL-POSS.PL:3PL
‘her/his jaws’

[8] Plosive deletion appears with these possessive markers after liquids similarly to the inflection suffixes – see section 7.2. Unvoiced stem codas which share or have similar place articulation as the possessive consonant onset also get voiced such as /rɛ̀ɐ̤ːt̪/ → rɛ̀ɐ̤ːd-ɛ̀.

Hybrid nouns with a L tonal tree ($^{\mathrm{L}}$) behave as stable stems and retain their L tone on the stem with L-toned possessive markers (187). One exceptional hybrid noun is found which gets a H tone (188). As example (182) above showed, this noun also stands out in the plural by failing to get a H tone in the nominative and by having an exceptional pattern also in the oblique case plural.[9]

(187) Hybrid stems: L-L pattern

a. rɛ̀ɐ̤ːd-ɛ̀ /$^{\mathrm{L}}$rɛɐ̤ːt̪/
dryness-POSS.SG:3SG
'her/his dryness'

b. rɔ̀aːm-dɛ̀ /$^{\mathrm{L}}$rɔaːm/
sheep-POSS.SG:3SG
'her/his sheep'

c. lɐ̤̀k-dɛ̀ /$^{\mathrm{L}}$lɐ̤k/
dream-POSS.SG:3SG
'her/his dream'

d. cɔ̤̀a̤ː-dɛ̀ /$^{\mathrm{L}}$cɔ̤a̤ː/
bone-POSS.SG:3SG
'her/his bone'

(188) Exceptional hybrid stem: H-L

ɟá̤ˑl-kɛ̀ /$^{\mathrm{L}}$ɟa̤ːl/
visitor\PL-POSS.PL:3SG
'her/his visitors'

The data in (185)–(188) support the dichotomy of stems showing that their tone behavior is consistent also with possessives. The tone in stable stems remains faithfully L, whereas unstable nouns get a polar tone with the possessive marker. These data also indicate that inflectional suffixes differ tonally from the possessive markers. While inflection suffixes are toneless and get a tone depending on their configurations (grammatical L tone or H tone epenthesis), possessive markers have an underlying tone which does not alter, regardless of the neighboring tones.

The H tone which appears on L tones of unstable stems is not (exclusively) a phonological phenomenon caused by OCP-L but relates to a grammatical phenomenon. The nominal constructions with these possessive markers are referred to as the 'construct state'. There appears to be the same phenomenon in Dinka. Andersen (2002) describes the construct state in Dinka as a pattern of segmental and suprasegmental changes to stems which occur with a modifier. Just as in Nuer, Dinka has a pattern of tonal polarity (referred to as 'construct 1' by Andersen 2002) with nouns with a possessive marker. Andersen (2002: 21) notes that the stems are L-toned before H-toned markers and are otherwise H-toned. In Nuer, the possessives appear to generally trigger a grammatical tone. The L → H pattern on the monosyllabic stems is not (or not only) conditioned by OCP-L because it also applies when the stems attach to a H-toned marker: the first person possessive *-dé̤*. In addition, there is a third derived opposite pattern where H-toned stems change to L when a possessive marker attaches. Regardless of this, the

[9] This stem gets shortened from a long vowel *ɟà̤ːl* to a mid-long vowel with the possessive marker. The other nouns such as *rɛ̀ɐ̤ːt̪* do not change the vowel length.

possessive markers show that the nouns react differently to this grammatical tone which supports the proposed classification of stems.

7.5.3 Post-lexical OCP-L and inflection

In the oblique case at the post-lexical level, H tone epenthesis works as an OCP-L repair in the same manner as was seen for the nominative case in chapter 5. The oblique case is built in constructions with a preposition or a preceding possessum noun. L tone sequences arise often in the oblique case because the exponence of this case is a L tonal tree. There are two different strategies for repairing OCP-L in these cases. Unstable stems get a H tone instead of the expected oblique L tone. This contrasts with stable stems which resolve OCP-L by inserting a H tone on the preposition or preceding possessum noun. This is shown below. In (189), the word *gékè̤* ends in a L tone. When this precedes the L-toned stem of the noun *kè̤ːr*, the preposition gets a downstepped H tone *gék*$^{\downarrow}$*é̤*. The stem gets a suffix which is targeted by H tone epenthesis because it is L-toned: *kè̤ˑr-é̤*. The same can be observed for the stable nouns in (190) and (192). The noun *tɔ̤̀t* 'summer' does not have a suffix in the oblique case, but it behaves as a stable stem by being immune to H tone epenthesis and by getting a suffix in the nominative plural.

In comparison, the unstable stems in (191) and (193) have a floating lexical tone underlyingly (marked by a tone in superscript). They get a L tone in the oblique case regardless of their floating lexical tone. For example in (191), the noun has a H tone in the nominative. When it follows a H-toned possessum as in (191a), it gets an oblique L tone. When however, it follows the L-final preposition *gékè̤*, the expected oblique L tone does not appear; instead H tone epenthesis applies. Because it is an unstable noun, the H tone targets the noun stem instead of the preposition (191b). The same applies to *lɔ̀ɲ* 'lion' in (193) – see footnote 10 below concerning its HL tone.

Stable stems

(189) Nominative: kè̤ːr
/gékè̤ kè̤ˑr-e̤/
gé$^{\downarrow}$ké̤ kè̤ˑr-é̤
next.to line-OBL.SG
'next to the line'

(190) Nominative: gwàk 'fox'
/gékè̤ gwàk-e̤/
gé$^{\downarrow}$ké̤ gwàk-é̤
next.to fox-OBL.SG
'next to the fox'

Unstable stems

(191) Nominative: d̪ó̤ːl
a. /míɛˑm ^{H}d̪ʊl/
míɛˑm d̪ʊ̀l
hair boy\OBL
'the hair of the boy'

b. /gékè̤ ^{H}d̪ʊl/
gékè̤ d̪ʊ́l
next.to boy\OBL
'next to the boy'

Stable stems

(192) Nominative: tɔ̤̀t
/gékɛ̤̀ tɔ̤̀a̤t/
gé↓kɛ̤́ tɔ̤̀a̤t
next.to summer\OBL
‘next to the summer’

Unstable stems

(193) Nominative: lòɲ
a. /míɛˑm ^{L}luɔˑɲ/
míɛˑm lùɔˑɲ
hair lion\OBL
‘the hair of the lion’
b. /gékɛ̤̀ ^{L}luɔˑɲ/
gékɛ̤̀ lûɔˑɲ
next.to lion\OBL
‘next to the lion’

The same dichotomy of OCP-L repair mechanisms applies in genitive constructions with two L-toned nouns. When stable stems are the possessor noun, they are not affected by H tone epenthesis. Instead, the tone of the possessum noun to the left is raised and their L tone surfaces with a downstepped H tone. This is shown in (194b) where the noun *cɔ̤̀a̤ː* gets a ↓H tone before the stable possessor noun *gwàk*. The same happens in (195) and (198a)–(198b). The mirror image of OCP-L repairs can be observed for unstable nouns. The noun *lò*ɲ ‘lion’ has a L tone in the nominative case which stays L in the oblique case (196a). When it follows a L-toned noun like *cɔ̤̀a̤ː*, it is targeted by H tone epenthesis and surfaces with a ↓H tone (196b). Similar cases can be observed in (197), (199), and (200)–(201). Note that H tone epenthesis surfaces as a ↓H here because the oblique L tonal tree delinks from its root node – see section 9.2.1.[10]

Stable stems

(194) a. ɟɔ̂ˑ gwàk-ɛ̤́
behind fox-OBL.SG
‘behind the fox’
b. /cɔ̤̀a̤ː gwàk-ɛ̤/
↓cɔ̤́a̤ː gwàk-ɛ̤́
bone fox-OBL.SG
‘the bone of the fox’

(195) a. /bîɛl kɛ̤̀ˑr-ɛ̤/
bîɛl kɛ̤̀ˑr-ɛ̤́
color line-OBL.SG
‘the color of the line’
b. /nɛ̤̀ˑn kɛ̤̀ˑr-ɛ̤/
↓nɛ̤́ˑn kɛ̤̀ˑr-ɛ̤́
mirror line-OBL.SG
‘the mirror of the line’

Unstable stems

(196) /^{L}loɲ/ lion’
a. míɛˑm lùɔˑɲ
hair lion\OBL
‘the hair of lion’
b. cɔ̤̀a̤ː ↓lúɔˑɲ
bone lion\OBL
‘the bone of the lion’

(197) /^{L}waŋ/ ‘eye’
a. bîɛl wàˑɲ
color eye\OBL
‘the color of the eye’
b. /gwɔ̤̀p ^{L}waŋ/
gwɔ̤̀p ↓wáŋ
skin eye\OBL
‘the skin of the eye’

[10] Some speakers realized a HL tone on the unstable nouns instead of a downstepped H tone. It is unclear whether it is simply variation or due to other factors..

Stable/hybrid stems

(198) a. /rɛ̀ɐ̤ːd tɔ̤̀t/

↓rɛ́ɐ̤ːd tɔ̤̀a̤t
dryness summer\OBL
'dryness of the summer'

b. /kḛ̀ːr nḛ̀ˑn-ɐ̤/

↓kḛ́ːr nḛ̀ˑn-ɐ̤́
line mirror-OBL
'the line of the mirror'

Unstable stems

(199) /^{HL}dɛˑl/ 'sheep/goat'

a. bîɛl dɛ̀ɐ̤ːl
color sheep\OBL
'the color of sheep/goat'

b. cɔ̤̀a̤ː ↓dɛ́ɐ̤ːl
bone sheep\OBL
'bone of sheep/goat'

(200) /^{H}d̪o̤ːl/ 'boy'

a. míɛˑm d̪ʊ̀l
hair boy\OBL
'the hair of the boy'

b. lɔ̀ɲ ↓d̪ʊ́l
lion boy\OBL
'the lion of the boy'

(201) /^{H}mun/ 'soil'

a. wíˑ mṳ̀ɔ̤ːn
on soil\OBL
'on the soil'

b. gùɛˑj ↓mṳ́ɔ̤ːn
stone soil\OBL
'stone of the soil'

The contrasting patterns of H epenthesis according to the stem types is very consistent, and only one exception has been found with *lwâˑk* 'cattle hut'. It has the properties of an unstable noun because it forms the oblique case by getting a L tone and segmental stem-internal modifications (202a). However, H tone epenthesis targets the possessum nouns as if it were a stable noun (202b). One would expect *kḛ̀ːr ↓lwáːk* but instead, the surface tones are *↓kḛ́ːr lwàːk*.

(202) /kḛ̀ːr 'line' – ^{HL}lwaˑk/ 'cattle hut'

a. bîɛl lwàːk
color cattle.hut\OBL
'the color of the cattle hut'

b. ↓kḛ́ːr lwàːk
line cattle.hut\OBL
'the line of the cattle hut'

7.6 Discussion

7.6.1 Alternative approaches

The stem classification I have proposed – stable, unstable, and hybrid – is empirically motivated by the behavior of the stems in relation to tonotactics at the phrase level in the nominative case and oblique case and the distribution of suffixes in inflection. This classification overlaps with other properties of nouns in Nuer such as voice quality and stem complexity. Because of this, I do not exclude that the stable – unstable division and the simple/complex stem classification are groupings in Nuer which overlap. If a stem can take an inflectional suffix as in the oblique case, it might relate to both the fact that it is a stable noun and its classification as a complex stem (breathy, long, and grade 3 vowel). Similarly, if the stem cannot take an inflectional suffix, this might be related to both the fact that the stem is unstable or simple. There are a few reasons why stem classifications based strictly on tone are the favorable approach compared to classifications related to stem complexity.

Stems with breathy vowels are often classified as complex stems in Western Nilotic. There is a tendency for plurals to have breathy vowels, but singulars can also be breathy. In section 7.1, it was mentioned that complex stems in Dinka tend to have grade 3 vowels and diphthongs, overlong vowel length, and/or breathy vowels (Andersen, 2002). There are several reasons why the Western Nilotic notion of stem complexity cannot capture the behaviors of nouns concerning tone and suffix distribution. First, I showed that vowel alternations are mostly independent of tone. Second, stems are mostly complex in the oblique case. Nevertheless, stems differ in this case form in that some stems get suffixes and are immune to H tone epenthesis (stable nouns), while other stems undergo stem-internal modifications and are subject to H tone epenthesis (unstable stems). For example, the stable noun *rɛ̀ɐːt̪* ‘dryness’ has a complex stem (diphthong, long breathy vowel), and the oblique case form is *rɛ̀ɐ̤ːd̪-é*. However, the noun *lɔ̀ɲ* ‘lion’ is an unstable stem which also gets a complex stem in the oblique case *lùɔˑɲ*. Thus, it could not be predicted why in the oblique case, where all nouns are considered to have a complex stem, only one group of nouns are subject to L tone overwriting and H tone epenthesis (unstable nouns) while another group is not subject to this (stable nouns).

Another related possibility concerns phonation, as many of the stable nouns have a breathy vowel. A plausible alternative to the stable – unstable stem classification would be to say that stems with breathy vowels are immune to H tone insertion in constructions with OCP-L violations. Modal vowels, on the other hand, would not have this restriction and H tone can replace their L tone. It is in fact true that many of the stable and hybrid stems have a breathy vowel in the nominative: *nè̤ˑn* ‘mirror’, *kè̤ːr* ‘line’, *rɛ̀ɐ̤ːt̪* ‘dryness’. However, there are several stable and hybrid stems with a modal vowel. For example *gwàk* ‘fox’ and *rɔ̀aːm* ‘sheep’. In addition, this account would fail under the assumption that the plural involves a H tone which goes on the stems of monosyllabic nouns because these are in fact mostly breathy. That is, if breathy stems are immune to H tone epenthesis as a possessor noun, it would be expected that they also cannot take other tones. One solution to this would be to assume that the H tone is lexically specified for plural stems separately from singular stems. I argue that, the stem division of stable, hybrid, and unstable nouns is a more simple approach than referring only to phonation because the latter would require more levels of lexical specification.

7.6.2 OCP-L vs. head-marking

The H tone pattern in Nuer has been generalized as a phonological phenomenon triggered by OCP-L. In constructions with two nouns, the H tone which appears on possessum nouns when the possessor noun has a stable stem is strikingly similar to head-marking. This H tone also appears as a grammatical tone in languages related to Nuer.

In the Western Nilotic language Shilluk, a H tone pattern is found in the plural of the head-marking form referred to as pertensive (posssessive or genitive marking on the possessed item, see Dixon 2010). In a possessed noun phrase as in (203), the noun 'trumpet' is inflected for the number of the possesors. In (203a), it is inflected for singular and has the form *kа̋aaŋ̄* because the possessor noun, *kùl*, is singular. In (203b), the possessor noun, ɟìɪ, is plural and therefore, the possessed noun is inflected for plural and has a H tone *káaaŋ*.

(203) Shilluk (Remijsen et al., 2018: 9)

a. ka̋aaŋ̄ kùl
trumpet:PERT.SG Kul
'Kul's trumpet'

b. káaaŋ ɟ̀ìɪ
trumpet:PERT.PL person:PL
'peoples trumpet'

If the base form is L, as in *gʌ̀ʌt* 'river bank', the plural pertensive form adds a H tone which creates a rising tone and a long vowel *gʌ̌ʌʌt*. The singular pertensive form is L: *gʌ̀ʌʌt* (Remijsen et al., 2018: 9).

Dinka is a language with both head-marking and dependent-marking. In section 7.5.2, I mentioned that the polar pattern on unstable nouns is very similar to the construct state in Dinka. The term construct form (cf. Creissels, 2006) is a notion adopted from Semitic linguistics which refers to morphological head-marking. Besides Semitic languages, the construct form has been found in several East-African languages such as Hausa, Wolof, and Tswana.

In Dinka, nouns are segmentally and tonally marked when modified in the DP. Nouns with a possessive marker are referred to as the construct state II (Andersen, 2002). This form differs segmentally and tonally from the nominative form. Dinka nouns also have dependent-marking for case. An example is shown in (204). The possessed noun *mɛ̰̀t̪* 'child' has a L tone (204a) which changes to H when it modifies the possessor in (204c): *má̰n̪*. The possessor noun *bá̤ŋ* has a H tone (204b) which changes to L in the oblique form in (204c): *bà̤ŋ*.

(204) Dinka (Andersen, 2002: 15)

a. mḛ̀t̪ 'child'

b. bá̤ŋ 'chief'

c. má̰n̪ è̤ bà̤ŋ
child:CS1 PREP chief:OBL
'the chief's child'

The similarity between (204) and the constructions in Nuer in this chapter is striking. If there were no evidence for OCP-L in the nominative case, it would be reasonable to consider H tone epenthesis on possessive nouns as a purely grammatical phenomenon. However, since there is evidence of OCP-L in constructions outside possessives, I see it as a phonological phenomenon. On this note, when the data from Dinka and Shilluk are considered, it seems that Nuer might be in transition from a head-marking language to a dependent-marking language. The H tone appearing on possessor nouns can also be considered a grammatical tone as in Dinka. The fact that it only appears with stable nouns indicates that it might be disappearing and Nuer is developing into a dependent-marking language. Because the OCP-L is prevalent in many other constructions, I consider the H tone on possessor nouns as the repair of OCP-L, but I do not exclude that the H tone has had a grammatical function previously.

7.7 Summary and overview of exponence

In this chapter, I have argued that Nuer has tonal and suffixal exponents for case and number. The tonal exponents are a H tonal tree marking plural number and a L tonal tree marking the oblique case. An overview is given in (205).

(205) Tonal and suffixal exponence exponence of case and number in Nuer (final)

a. H(L) tonal tree$_{\text{[PLURAL]}}$

b. L tonal tree$_{\text{[OBLIQUE CASE]}}$

c. -kɐ̤$_{\text{[SG, OBLIQUE]}}$

d. -ni̤$_{\text{[PL]}}$

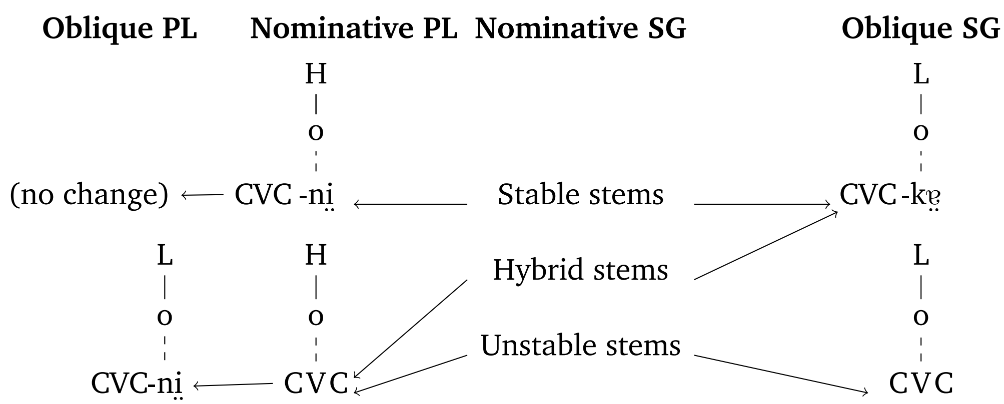
With these exponents, the classification of stable, hybrid, and unstable nouns is sufficient for accounting for surface tonal patterns and the suffix distribution. That is, it can predict the distribution of *-kɐ̤* and *-ni̤* vs. stem-internal modifications with the surface tones. These distinctions are phonologically motivated, relying on stem defectiveness of tone. Stable stems get suffixes in case and number inflection and are generally immune to H tone epenthesis with

OCP-L violations, while unstable stems remain monosyllabic and get inflectional tones and H tone epenthesis on their stems. Hybrid nouns are a category in between these two distinctions. They remain monosyllabic in the plural nominative and surface with a H tone on their stems, but they get a suffix in the oblique singular forms and are immune to H tone epenthesis. All the properties are summarized below, and an overview of the inflectional exponence is given in the diagram in (206).

Inflectional exponents according to stem type

- Stable stems = always suffixable:
  - -*ni̤* surfaces with a H tone in the plural nominative
  - -*kḛ̤* surfaces with a L tone in the oblique singular
  - Generally not target for H tone epenthesis in OCP-L violations
- Hybrid stems = suffixable in singular oblique but not in plural nominative:
  - Surfaces with a H tone in the plural nominative
  - -*kḛ̤* surfaces with a L tone in the oblique singular
  - Generally not target for H tone epenthesis in OCP-L violations
- Unstable stems = never suffixable:
  - Surfaces with a H tone in the plural nominative
  - Surfaces with a L tone in the oblique singular
  - Target for H tone epenthesis in OCP-L violations

(206) *Diagram of exponents for stable, hybrid and unstable stems:*



Chapter 8

Theoretical background

This chapter outlines the theoretical background which is essential for the analysis in the following chapter. The analysis I propose is a concatenative approach to nominal inflection. In a nutshell, general phonological processes derive the surface alternation between tone mutation and suffixation. I argue that this alternation arises due to an interplay between defective stems and defective affixes, a so-called bidirectional defectiveness. This component of the analysis involves enrichment of autosegmental structure in line with the concatenative approach called the Generalized Nonlinear Affixation (GNLA) (cf. Bermúdez-Otero, 2012; Trommer, 2011; Trommer and Zimmermann, 2014). Section 8.1 discusses some of the ideas behind GNLA and the benefits of this research program in comparison to non-concatenative approaches. According to Bermúdez-Otero (2012), the concatenative approach to morphology in GNLA follows from the *Morph Integrity Hypothesis* which is part of a Four-Hypothesis program. In section 8.2, I outline some of the primary points of these restrictions on the morpho-phonology interface, which allow for a clear distinction between the morphology and phonology in Nuer inflection.

A concatenative approach of mutation goes hand in hand with a stratal derivation. The second component of the analysis is the organization of the grammar. There is evidence of a serial interaction between tone and segments in Nuer inflection. My proposal relies heavily on the idea that phonology applies cyclically over morpho-syntactic domains. I propose a Stratal OT analysis for these tonal interactions in Nuer. The approach I adopt is by Bermúdez-Otero (1999, 2011, 2012). The main components of this theory are sketched out in section 8.3.

The first component of the analysis, the enriched autosegmental structures, was introduced in chapter 5 where the branching structure by Yip (1989) was adopted for HL tones. In her approach, root nodes are used as an intermediate layer between the Tone Bearing Unit and the tones. This structural enrichment becomes necessary for the three-way distinction between stems: stable, hybrid, and unstable. The general autosegmental operations of deletion and spreading which I assume for the analysis in Nuer are explained in section 8.4 along with some of the general constraints in Correspondence Theory of OT. Section 8.5 summarizes.

8.1 Generalized Non-linear Affixation

The division between phonology and morphology is mostly uncontroversial for standard concatenative morphology such as adding a segmental morpheme like a suffix, a prefix, or an infix. For example, the plural marker *-s* in English should be considered a morphological component when it is added to a singular form, e.g., *cat-s* [kæts]. It is then the phonology which alters the featural specification according to the neighboring phoneme of this plural marker. Depending on the approach, one might consider the plural as a voiceless consonant which is realized as voiced if, i.a., the singular stems end in a voiced coda, e.g., *dog-s* [dɔgz].

This is more complicated in Nuer because there is both linear and non-linear morphology, and the division of morphology and phonology is not clear-cut at first sight. If only the segmental aspect of inflectional suffixation is considered, the distribution of *-kɛ̤* and *-ni̤* is merely a case of lexical allomorphy as has been previously analyzed (Frank, 1999; Baerman, 2012). When tone comes into the picture, it presents a non-linear part of the morphology involving tonal mutations in the stems. The last chapter showed that depending on the tonal nature of the stem, a noun either gets a suffix or undergoes mutation. Stems such as *nɛ̤̀ˑn* 'mirror' involve linear morphology because a suffix is added to the stem in the oblique case: *nɛ̤̀ˑn-kɛ̤́*. For other stems, the tone undergoes mutation from H to L, and no suffix attaches to the stem. For example, the noun *d̪ɔ̤́ːl* 'boy' has a high tone which undergoes mutation in the oblique form and changes to L: *d̪ʊ̀l*. The interesting aspect with this pattern is that general phonological processes can correctly derive the surface distribution which alternates between mutation and suffixation by taking a concatenative approach to morphology.

Mutation is often analyzed in non-concatenative approaches. Non-concatenative theories involve word-formation rules, readjustment rules, cophonologies, and using constraints in OT which refer to morph-specific information (e.g., indexed constraints or OO-identity) (see Trommer 2011; Bermúdez-Otero 2011; Trommer and Zimmermann 2014, for discussions on this). Some of the problematic aspects with non-concatenative approaches which have been mentioned in the literature regard the fact that they are not restrictive enough to allow for a modular approach to the interfaces between syntax, morphology, and phonology. This can easily lead to analytic underdetermination which poses a threat to falsifiability and learnability (cf. Bermúdez-Otero, 2012).

The analysis I propose in the next chapter is a concatenative approach to the mutation–suffix alternation in Nuer where the division between morphology and phonology is clearly defined: the morphology inserts inflectional affixes (segmental, tonal, or both), while the phonology derives the alternations between mutation and suffix realization. This is in line with the research program named Generalized Nonlinear Affixation (GNLA) (cf. Bermúdez-Otero, 2012), developed primarily by Trommer (2011); Trommer and Zimmermann (2014). The main idea of this research is that all morphological processes can be reduced to concatenative processes. The aim is to reduce productive instances of non-concatenative morphology to general processes of concatenative affixation of defective phonological material; e.g. mora affixation, floating tones, or empty foot nodes (Trommer and Zimmermann, 2014). As stated in Trommer and Zimmermann: 506, the model "equates the triggers of non-concatenative processes with simple, but incomplete, autosegmental and prosodic representations."

For example, Trommer and Zimmermann (2014) analyze phenomena related to morphological length, i.e., *Quantity-Manipulating Morphology*, as concatenative processes. This approach is named *Generalized Mora Affixation*. Generalized Mora Affixation offers many advantages in comparison to non-concatenative approaches by reducing allomorphic processes to phonological effects triggered by a single morpheme representation. With autosegmental structures, phenomena such as moraic subtraction arise as a phonological side-effect caused by affixation of moras which have different levels of prosodic defectiveness.

In GNLA, the focus lies on defectiveness of affix material. An affix is defective if it lacks segmental structure and consists solely of a prosodic element such as a floating mora, or if it only consists of a floating phonological feature. Non-segmental material such as floating tones, moras, and feet are assumed to behave as segmental affixation in that they can be suffixed, prefixed, or infixed. The general mechanisms at work in the GNLA analyses have been applied to a series of segmental and supra-segmental phenomena in several Western Nilotic languages, which have a rich non-linear morphology (see Trommer 2011). The mutation of Nuer can easily be captured in a concatenative approach in line with GNLA. The new aspect of my proposal regards the fact that defectiveness in stems plays an equally important role as defectiveness in affixes. The details on this are given in the next chapter in section 9.1.

The remainder of this chapter introduces some concepts which are essential to the proposal of Nuer nominal inflection starting with restrictions on modularity.

8.2 Principles of modularity

I adopt the Four-Hypothesis Program outlined by Bermúdez-Otero (2012) which restricts the interactions between morphology and phonology. The purpose is to limit analytic underdetermination which easily arises with phenomena where alternations are due to both morphological, phonological, and lexical factors. In other words, cases such as nominal inflection in Nuer where not only lexical tones interact with inflectional tone, but these tonal components are restricted by OCP-L.

In the approach by Bermúdez-Otero, the phonology can only access a limited amount of morpho-syntactic information such as the edges of prosodic categories. This is implemented in OT by alignment constraints (McCarthy and Prince, 1993). The phonology cannot access information besides this such as morphological features. This is referred to as the Indirect Reference Hypothesis which states that phonological rules or constraints do not apply directly to syntax or morphology (207). Instead, the phonology applies to an intervening prosodic representation which maps morpho-syntactic units to prosodic units (Nespor and Vogel, 1986; Selkirk, 1984; Truckenbrodt, 1995, inter alia).

(207) *Indirect Reference Hypothesis* (Bermúdez-Otero, 2012: 77)
A phonological constraint may not refer to syntactic, morphological, or lexical information unless to require alignment between designated prosodic units and the exponents of designated syntactic (word-syntactic or phrase-syntactic) nodes.

Similarly, for the morphology, I adopt the assumption that morphological operations cannot alter the phonological content of morphs or syntactic information. This is referred to as the *Morph Integrity Hypothesis* (208) (Bermúdez-Otero 2012: 50, see also Trommer 2011 for a discussion of this). As Bermúdez-Otero observes, this predicts that all morphology is concatenative.

(208) *Morph Integrity Hypothesis* (Bermúdez-Otero, 2012: 50)
Morphological operations do not alter the syntactic specifications or phonological content of morphs.

The third hypothesis is the Phonetic Interpretability Hypothesis which states that phonological representations need to be phonetically interpretable (209). This ensures that the phonological output form does not contain morphosyntactic information such as morpheme boundaries. This entails a form of *Bracket Erasure* where the internal brackets of a structure which shows its morphological boundaries at one point in a serial derivation become invisible at a later point in the derivation.

(209) *Phonetic Interpretability Hypothesis* (Bermúdez-Otero, 2012: 81)
The contents of phonological output representations are phonetically interpretable.

The hypotheses in (207)–(209) restrict the type of constraints which I use in the analysis on Nuer – see section 8.4 and chapter 9. The Phonetic Interpretability Hypothesis relates to the fourth hypothesis which regards the cycle and will be discussed more extensively in the next section.

8.3 Stratal Optimality Theory

The second component of my proposal relies on the idea that the phonology applies cyclically using Stratal Optimality Theory (Kiparsky, 2000, 2015; Bermúdez-Otero, 2011, 2012). Stratal OT is a branch in Optimality Theory (OT) (Prince and Smolensky 1993/2004), a framework which models or derives how grammar works in a given language. The word 'stratal' refers to the serial mechanism of this model. It relies on the assumption that phonology applies cyclically over morpho-syntactic domains. These domains are referred to as strata or levels in the grammar. The data in this study are analyzed in Stratal Optimality Theory using the approach by Bermúdez-Otero (2011, 2012) where each stratum is a cycle. This differs from the approach by Kiparsky (2000, 2015) where each stratum can have several cycles.

Classic OT can be described as a piece of machinery consisting of two mechanisms. The generator (GEN) takes an input form and generates output forms. The other component, EVAL, evaluates the input form against the output forms with the help of a set of ranked constraints. It then selects the optimal output form among these candidates. The constraints are violable and restrict either the application of a process or simply a structure per se – more on this in section 8.4. The mechanism of OT lies in taking an input and generating all kinds of output candidates which differ from the input. GEN generates an infinite number of output forms, but only the ones which violate the highest ranked constraints are typically shown. The evaluation component evaluates each candidate by registering their violations of each constraint. An asterisk signals such violations (here, I use a star '⋆'). An exclamation mark with a star shows a fatal violation (!⋆). Constraints can be gradient in that they are violated several times by the same candidate. The generator selects the output which induces the least violations of the constraint ranking. This is the winner, also known as the optimal candidate and is indicated by the hand '☞'. The winner represents the surface structure observed in a given language. The constraints are considered to apply universally to languages, but the rankings are language-specific. Thus, a given ranking stands for a grammar in a language. All constraints are technically present in a grammar, however only the most relevant ones (the highest ranked ones) are shown.

In classic OT, the evaluation of phonological structures happens globally. That is, the input is mapped to the output in one step. This approach is referred to as parallel because there are no intermediate stages in the derivation, and all candidates are evaluated at the same time. Stratal OT, on the other hand, relies on the idea that there are intermediate levels between the input and output. The evaluation is not finished after the optimal candidate has been chosen. Instead, the winner of one evaluation feeds into the next evaluation where it becomes the input. In this sense, the winner at one level is a local winner which is optimal at an intermediate stage. Strata or levels refer to the grammatical domains where phonological processes apply. In this sense, the phonology applies cyclically over local morpho-syntactic domains. To understand this, a few things need to be outlined regarding the cycle.

The cycle is a fundamental principle in Stratal OT. It is the fourth postulate of the hypotheses on modularity – see section 8.2, namely the Cycle Hypothesis. This hypothesis asserts that "certain morphosyntactic constituents define domains over which the phonology applies iteratively, starting with the most deeply embedded domains and moving progressively outwards"

(Bermúdez-Otero, 2012: 44). This concept of cyclicity is present in many different theories such as SPE (Chomsky and Halle, 1968), Lexical Phonology (Pesetsky 1977; Mohanan 1982; Kiparsky 1982a,b; Pulleyblank 1986, among others), Lateral Phonology (Scheer, 2004), and Phase Theory (Newell, 2008; Embick, 2014; D'Alessandro and Scheer, 2015). Broadly put, the cycle refers to local domains corresponding to grammatical constituents where phonological processes apply. Bermúdez-Otero (2011) uses the term 'cyclic node' to refer to such domains. In the Stratal OT approach by Bermúdez-Otero (2018), these cyclic nodes correspond to strata or levels. I adopt his assumption that only certain morphosyntactic constituents can constitute cyclic nodes: stem, word, and phrase.

The concept behind Stratal OT was developed in the rule-based framework known as Lexical Phonology. The main idea of Lexical Phonology was that there are systematic differences between lexical and postlexical phonological processes. Derivations in this framework involved intermediate levels between the underlying representation and the surface representation. Stratal OT can be viewed as a more restrictive theory than Lexical Phonology where the intermediate forms are limited to stem, word, and phrase level, and there are constraints instead of rules.

The cycle is typically needed to derive cases of phonological opacity such as counter-feeding and counter-bleeding. Feeding is when a phonological process A creates an environment which allows another process B to apply. On the contrary, a phonological process A bleeds another process B if A prevents B from applying. That is, if process A changes the environment which would have allowed process B to apply. While parallel OT handles cases with feeding or bleeding well, classic parallel OT cannot derive opacity effects such as counter-feeding and counter-bleeding. Counter-feeding is when a process underapplies. In other words, when a process could have fed another process, but it does not. Counter-bleeding is when a process overapplies. That is, when a process A could have bled another process B, but B still applies. A classic example of opacity involves affixes which trigger different phonology depending on the structure it attaches to. Below, I illustrate an example of counter-bleeding which has been analyzed in Lexical phonology (Borowsky, 1993) and in Stratal OT (Bermúdez-Otero, 2011).

Post-nasal plosive deletion in English is a classic example of counter-bleeding (see Borowsky, 1993). Homorganic consonant clusters with a nasal followed by a non-coronal voiced plosive such as [b] or [ɡ] in modern English is only allowed if the latter is in an onset position: *elongate* [ˈiːlɒŋ.ˌɡeɪt]. In a coda position, it undergoes deletion *long* [lɒŋ]. An interesting case can be observed in forms such as *longish* where plosive deletion overapplies. The /ɡ/ is expected to be in an onset position and to be realized as in *[ˈlɒŋ.ɡɪʃ]. Instead, it is deleted surfacing as [ˈlɒ.ŋɪʃ].

The difference between cases like [ˈiːlɒŋ.ˌɡeɪt] and cases with overapplication such as [ˈlɒ.ŋɪʃ] can be explained by looking at the morphological structure of the words. In Lexical Phonology, suffixes such as *-ate* in *elongate* are considered level 1 affixes which attach to the stem in the first cycle of phonological evaluation. On the other hand, suffixes such as *-ish* in *longish* are considered level 2 affixes which attach to the stem at a later cycle compared to level 1 affixes (Borowsky, 1993).

Bermúdez-Otero (2011) also suggests that there are structural differences between these words as illustrated by the brackets in (210) below. The derivations illustrate how the cycle works in Stratal OT. The inner cycle corresponds to the stem-level while the outer cycle corresponds to the word-level. The form in (i), [[lɒŋg]], is a word which consists of a simple stem. Deletion of /g/ happens because the plosive is in a coda position. This process applies in the inner cycle. In the outer cycle, there is nothing more to do, and the final output form is [lɒŋ]. The form [[iː-lɒŋg-eɪt]] in (ii) is structurally different in that [lɒŋg] is a verbal root which forms a stem together with the prefix [-iː] and the suffix [-eɪt]. This is marked by having the whole form in the inner-most bracket. At the stem-level in the inner cycle, the plosive becomes the onset of the suffix, and deletion does not apply for this reason. This contrasts with [[lɒŋg]ɪʃ] in (iii) where *long* forms a stem as in (i). The morpho-syntactic structure is different from the form in (ii) in that the suffix [-ɪʃ] belongs to the word level (outer cycle). The stem [lɒŋg], therefore, meets the condition of the deletion rule at the stem level (inner cycle). The suffix attaches at the word level after the deletion has applied. In other words, plosive deletion overapplies because the suffix [-ɪʃ] would have provided the right environment for /g/ to be realized in an onset position. However, it appears too late, i.e., at the word level where deletion has already taken place.

(210) Bermúdez-Otero (2011: 2020)

	i. [[lɒŋg]]	ii. [[iː-lɒŋg-eɪt]]	iii. [[lɒŋg]ɪʃ]
inner cycle	lɒŋ	iː.lɒŋ.geɪt	lɒŋ
outer cycle	–	–	lɒ.ŋɪʃ

There are several benefits to using the framework Stratal OT. First, Stratal OT gives rise to some valuable insights. One postulate is the called the Russian Doll Theorem (Bermúdez-Otero, 2011) which is an entailment of the cyclic theory. It predicts that if a phonological process is opaque, e.g., at the word level, it will also be opaque at the phrase level. According to the Russian Doll Theorem, it is expected that plosive deletion in English overapplies at the phrase level because it overapplied in earlier cycles. This prediction is borne out. At the phrase level, /g/-deletion also applies across words boundaries. When a vowel-initial noun follows *long* such as *effect*, resyllabification would provide the necessary condition for /g/ to be realized in an onset position: *[lɒŋ.gi.fɛkt]. Instead, overapplication of plosive deletion also applies at the postlexical stratum: [lɒŋifɛkt]. In other words, overapplication of a phonological process at the stem level entails overapplication at a higher level such as the word or phrase level.

Second, Stratal OT can capture generalizations which refer to intermediate stages of a derivation. This allows for insights which are not possible in parallel OT. For example, the cyclic approach illustrated in (210) gives transparency to plosive deletion because the phonological process is possible to detect at each stratum. The morpho-syntactic structure of these constructions independently motivate these strata. Stratal OT allows for different rankings of each stratum. This can also be a way of capturing generalizations of intermediate forms. It presents the possibility for constraints to refer to different stages in the derivation as was seen in (210) above so that different phonological predictions can be made for each stratum in a language. In this way, the constraints in a serial approach perform a local comparison of candidates at different levels as opposed to a global comparison of the candidates in a parallel approach. This system creates sub-grammars which can capture generalizations beyond the underlying structure and the surface form.

Third, the strata have a function of demarcating the morpho-syntax from the phonology. In the morpho-phonology interface, the cycle restricts the application of a given set of rules or constraints rather than having them apply globally to all levels of the grammar. In this way, the cycle can have a key function in maintaining modular restrictions on the morpho-phonology interface (Bermúdez-Otero, 2012). As stated in this paper, the Cycle Hypothesis has the "...effect of tightening up the locality restrictions associated with the cycle..." (Bermúdez-Otero, 2012: 49). Cyclicity enforces locality effects in phonological derivation because information in one cycle is not accessible in later cycles. It is a consequence of the architecture of Stratal OT that morphosyntactic structure, e.g. at the stem level, is not visible at the word or phrase level for the following reason. The word level input does not include the stem-level input, and the phrase-level input includes neither the stem-level, nor the word-level input (Trommer, 2011).

Besides the abundant evidence of cyclic behavior of affixes, non-linear morphology often relies on a serial derivation when analyzed as concatenative phenomena. Trommer (2011) shows how it is not a trivial task for classic parallel OT to derive cases with mutation without turning to faithfulness constraints which refer directly to floating material. For example by using constraints such as MAXFLOAT (Wolf, 2007). The problem with such constraints is that they risk violating the restrictions on modularity by indirectly referring to a morphological category (Trommer, 2011). Other constraints which can deal with floating material is REALIZE-MORPHEME van Oostendorp (2005). This constraint is also not unproblematic and runs into difficulties in cases of multiple exponence (see Trommer 2011 for a discussion on this).

8.4 Constraints and autosegmental operations

The analysis I propose for Nuer uses two types of constraints: markedness and faithfulness constraints. I adopt the Correspondence Theory of faithfulness (McCarthy and Prince, 1995, 1999) where a correspondence relation is established between the input (I) and the output

(O). There are three types of faithfulness constraints: MAX, DEP, and IDENT. MAX-IO militates against deletion, i.e., an element which is in the input but not in the output. DEP-IO militates against insertion, i.e., an element in the output which is not in the input. IDENT-IO requires that an input value of a feature is preserved in the output.

To take an example, a faithfulness constraint such as MAX-σ requires that a syllable in an input structure must have an output correspondent. The EVAL function in OT compares the syllables of the output candidates against the input. If the input has a syllable which is deleted in an output candidate, this syllable has no correspondence in the output violating MAX-σ. Thus, a truly faithful output entails a candidate without any changes from the input. Markedness constraints, on the other hand, refer only to the output form and have specific requirements to the well-formedness of the phonological structure. For example, the markedness constraint *CODA militates against structures which have a coda in the output regardless of the input.

The autosegmental structures with root nodes shown in section 5.5 are central in the OT analysis of chapter 9. Most of the constraints refer to different kinds of operations and associations in the autosegmental structures. This approach is used in the Containment version of OT in (Trommer 2011; Trommer and Zimmermann 2014, inter alia), but also in Correspondence Theory (see e.g. Yip 2002). For some of the constraints which refer directly to the autosegmental associations, I adopt a correspondent version of the constraints proposed by Trommer (2011: 50) because they iconically illustrate the autosegmental operation of the constraints. This concerns mainly upwards and downwards linking between prosodic structure and tones. The two constraints below apply for the association between two targets, tones, and syllables. The constraint in (211) demands that tones are linked to a syllable militating against floating tones. This corresponds to the constraint *FLOAT in Yip (2002). The constraint in (212) militates against toneless syllables and requires that every syllable is linked with a tone. This constraint corresponds to SPECIFY (Yip, 2002).

(211) Downward linking: $\overset{\mathrm{T}}{\downarrow}\atop\sigma$
Assign a violation mark to every tone which does not immediately dominate a syllable.

(212) Upward linking: $\overset{\mathrm{T}}{\uparrow}\atop\sigma$
Assign a violation mark to every syllable which is not immediately dominated by a tone.

In autosegmental phonology, there is the so-called well-formedness condition which states, among other things, that association lines cannot be crossed. I assume that line-crossing is a violable constraint in Nuer which is always high-ranked. An example is the structure in (213) below where the epenthesized association line of the L tonal tree crosses the associated association line of the linked H tone. In Nuer, no output of the analysis involves any crossing of association lines.

(213) Line crossing

```
L  H
|  |
o  o
   |
   σ -σ
```

The insertion of elements as were observed in chapter 5 – see (102) – usually has the function of repairing a defective structure which is lacking some element. Underspecification or defectiveness can regard syllables which lack tones, or tones which are not linked to a target. As Yip (2002) states, underspecification usually appears in underlying structure while in the output, segments are usually specified. In the Stratal OT analysis which I propose, segments can be defective in the outputs from the stem level and the word level. At the phrase level, the outputs are specified. Furthermore, I assume that the input can contain different levels of defectiveness in Nuer: bare floating tones and floating tonal trees. Syllables can be defective by lacking a tonal specification. Healthy or non-defective syllables are linked with a tonal target via a root node, labeled 'stable nouns'. When syllables are toneless, I assume a three-way distinction of defectiveness which will be illustrated in section 9.1. The distinction is syllables with no tone (certain suffixes), syllables with a bare floating tone (unstable nouns), and syllables with a floating tonal tree, i.e., a floating tone associated to a root node (hybrid nouns). I assume that floating tones are subject to the same principles of being prefixed or suffixed to a morpheme (see Trommer and Zimmermann 2014 for details on this).

Prosodically defective structures where the inputs differ in tonal associations and floating material, such as the ones described in the previous paragraph, are predicted to exist under the concept of Richness of the Base. According to this principle, inputs are universal and unrestricted (Prince and Smolensky, 2004; McCarthy and Prince, 1995; Kager, 1999). To borrow the term from Trommer (2011), the approach in Nuer can be seen as 'The Richness of Defective Exponents'.

Floating tones are a major part of the analysis in Nuer and are essential for having a concatenative approach in the analysis. Floating tones arise through deletion of associated tones as in (99), they exist as defective suffixes, or they are part of a lexical entry. How OT deals with floating tones is extensively discussed in Trommer (2011). When defective material such as floating features is available in a structure, constraints which refer directly to them can easily become a trigger for morphological rules. For example in Nuer, I claim that a floating H tonal tree marks plural number. By using a constraint such as MAXFLOAT (Wolf, 2007), this would ensure the survival of this H tone. However, it could be considered an indirect way of giving a phonological constraint access to a morphological category such as plural. Thus, using such constraints might violate the hypotheses on modularity such as the Indirect Reference Hypothesis – see (207) above. To avoid this, I adopt the theoretical meta-restriction by Trommer (2011) 'No Explicit Floating' in (214) which states that phonological constraints cannot refer specifically to floating structure.

(214) *No Explicit Floating* (Trommer, 2011: 5)
No phonological constraint may refer specifically to floating structure (to phonological nodes not associated underlyingly to segments).

Prosodic unintegrated material such as floating tones is commonly assumed to be erased at the end of a phonological derivation. This concept is known as Stray Erasure (McCarthy, J., 1979; Steriade, 1982; Itô, 1986) and was introduced in Lexical Phonology. In Nuer, I assume that the domain of Stray Erasure is the phrase level. Floating tones and tonal trees between the stem and word strata, however, are not deleted. The fact that such floating tones survive in the intermediate outputs between the strata is a special property of Nuer nouns and a central aspect in the analysis. On the one hand, certain syllables such as the unstable nouns behave as toneless concerning tone mutation. On the other hand, they have a lexical tone which can be detected in contexts which do not involve mutation such as the nominative case in the singular form. In the feed-forward architecture of Stratal OT, this is captured by generating outputs with floating tones which are shipped to the next stratum without deletion. The floating tones become part of the input for the next stratum. At the phrase level, any floating tone which is not pronounced (either as a linked tone or downstep) is deleted as a Stray Erasure effect. In other words, floating tones are part of intermediate outputs in Nuer, but not of the final outputs.[1]

[1] See Paschen 2018 for the proposal 'Full Rebirthing' in Extended Containment Theory which proposes that unintegrated material is not deleted across strata.

8.5 Summary

This chapter introduced the main theories and hypotheses which will be relevant for the analysis of Nuer in the next chapter. This involved the framework Stratal OT and the principles of modularity which I adopt for the interface between morphology and phonology. Another vital principle regards the concatenative approach taken in order to account for the mutation patterns in Nuer, and I discussed that this is in line with the research program GNLA. Moreover, defective structures are central in this line of research. The new component I propose is that defectiveness not only concerns affix material such as floating tones, but also defective stems. The next chapter shows the details on enriched autosegmental representation with root nodes. The analysis seeks to capture how tone mutation alternates with suffixation using general phonological constraints under a stratal concatenative approach.

Chapter 9

Analysis

This chapter presents a Stratal OT analysis (Kiparsky, 2000; Bermúdez-Otero, 1999) of the interactions between inflectional tone, lexical tone, and OCP-L repairs in nouns. The proposal for Nuer involves a concatenative approach to tone mutation which accounts for the surface tones and the suffix distribution of nouns in number and case inflection. In a nutshell, the alternation between stem mutation and suffixation in Nuer nouns results from a serial interplay between defective stems and defective affixes. The patterns observed in chapter 7 revealed that either tone mutation or suffixation mark case and number. Instead of considering suffixation in Nuer as arbitrary allomorphy, I claim that it is phonologically predictable because it depends on layers of defectiveness. Although only some nouns get suffixes in the oblique case and plural, all stems are exposed to the same segmental and suprasegmental exponents in the input. I argue that these difference between mutation and suffixation are the outcome of a bidirectional stem–affix defectiveness. Tonal specification on syllables come in three broad types: (i) toneless syllables, as exemplified by certain inflectional suffixes such as *-ni̤* and *-kɐ̤*; (ii) intermediate tonal defectiveness, such as unstable stems with a floating lexical tone or hybrid stems with a floating tonal tree; and (iii) fully specified stems, such as stable stems. In addition, there are defective affixes consisting of floating tonal trees. The way these layers of defectiveness respond to case and number exponents determines whether a noun will surface with a suffix, or whether it instead takes an inflectional tone on the stem. The layers of defectiveness are independently motivated by how the stems respond to OCP-L repairs.

The idea of a bidirectional defectiveness is an extension of the research program GNLA, which states that non-linear morphology is due to defective affix material. Several studies have focused on defective affixes which consist of floating material – see references in section 8.1. This analysis is an extension of GNLA which employs defective segmental material, i.e., toneless syllables and defective supra-segmental material, i.e., floating tones.

The analysis is tone-driven and relies on a stratal derivation where case and number exponents appear at different levels in the grammar. It follows the approach by Bermúdez-Otero (1999) where the phonology applies cyclically over the stem, word, and phrase level. Each of these three domains forms a stratum which has a distinct constraint ranking – see the previous chapter for more on stratal OT. Moreover, the analysis shows how suffix patterns, which on the surface seem to require noun classes, can be derived by assuming different underlying representations with segmental and supra-segmental exponence appearing on different strata. The analysis relies heavily on the postulations that (i) floating tones and tonal trees which fail to link to a syllable at intermediate levels are *not* automatically deleted when the next level is evaluated but survive in the input, and (ii) toneless suffixes can only survive in the output if they get a tonal specification. If they do not get a tone, they will be deleted.

In the remainder of this chapter, section 9.1 presents the components of the analysis which regard bidirectional defectiveness. Section 9.2 provides an overview of the autosegmental mechanisms in the analysis of singular and plural stems. Section 9.3 presents the constraints and section 9.4 gives the rankings. Section 9.5–9.6 present the OT analysis of plural and singular nouns in the nominative and oblique case. Some nouns have irregular tone patterns and are discussed in section 9.7. Section 9.8 summarizes the chapter.

9.1 Bidirectional defectiveness

According to the 'Generalized Nonlinear Affixation', it is predicted that nonlinear or non-concatenative morphology applies in cases where defective material without segmental form (e.g., floating moras, tones, and features) attaches to a morphological base via phonological processes. As discussed in see section 8.1, the central idea in GNLA is that non-linear morphology arises due to defective affix material which causes changes in the base. When morphemes lack features such as a tone, they are commonly referred to as underspecified.

In this proposal of bidirectional defectiveness, stems can be defective by lacking a tonal specification, and tones can be defective if they lack a segment and float. The idea is that non-concatenative morphology applies when *both* stems and affixes are defective. This approach incorporates the following assumptions: morphemes in Nuer have a four-way distinction in tonal specifications. Nuer has (i) toneless syllables, (ii) floating tones (without any root node), (iii) floating tonal trees (tones associated to a root node), and (iii) syllables specified for tone. These tones, which differ in structure, are specified in the lexicon.

Chapter 7 argued that there are three kinds of stems in Nuer: stable, hybrid, and unstable. These stems interact differently regarding the case and number inflection and concerning H tone epenthesis. I showed that suffixes and some stems behave as if they were toneless because they get a different tone depending on the morphological case and phonological environment.

Other stems behave as syllables which are specified for tone. Recall that completely regular exponence happens with stable nouns. That is, suffixation happens in all forms except for the nominative singular – see chapter 7. On the other hand, non–linear exponence applies to defective structures such as hybrid and unstable stems. For example, hybrid stems have non-linear exponence in the plural nominative, and unstable stems have non-linear exponence in all forms except the oblique case plural. In other words, the fact that unstable stems undergo tone overwriting instead of taking a suffix indicates that they are defective. They are unstable because the stems rely on insertion of material such as (tonal) root nodes or grammatical tonal trees to get a tonal specification. The three-way distinction of the stems regards the nature of the associations of lexical tones at the stem level: stable stems have underlyingly a full structure: a lexical tone with a root node associated to a syllable (215). Hybrid nouns have a defective structure in that their lexical tone is a floating tone associated to root node, a 'floating tonal tree' (216). The unstable stem is more defective than the hybrid stem in that it has a floating lexical tone but lacks a root node (217). The tones are lexical and can be H, L, or HL.

Stem level inputs

(215) Stable stem	(216) Hybrid stem	(217) Unstable stem
T	T	T
$\vert$	$\vert$	
o	o	
$\vert$		
σ	σ	σ

This defective representation is similar to the moraic representations in Trommer and Zimmermann (2014: 468). Here, the hybrid stem is similar to the structure called a 'hanging mora' represented by a floating syllable associated to a mora but not associated to a segmental root node. The unstable stem is similar to the structure called a 'Stray mora' which has a floating syllable and a floating mora.

The fact that unstable stems cannot simply be represented as toneless is because if they were assumed as such, the prediction would be that these stems surface with a predictable tone in the nominative case. For example, they might surface with a default tone. Another possibility would be that they were subject to interpolation of f_0 when they are between two tonally specified targets. None of those predictions are borne out because they show up with lexical tones in the nominative case. That is, they get a H, L, or HL which cannot be predicted by surrounding tones or other factors. Therefore, this analysis has to capture that these stems do in fact have a lexical tone, but it can only surface in the nominative case when there are no OCP-L violations.

Affixes concern any material which changes the meaning of the root via inflection or derivation. The grammatical tones in inflection are defective in that they are floating tonal trees which lack a segment to link to. In the input, they appear with a root node. A L tonal tree is the exponent for the oblique case (218), while the plural exponent is a H tonal tree which floats (219). The latter has a HL tonal tree allomorph which is lexically specified and floats as a unit associated to a root node (220). The segmental affixes are also defective by being toneless. The suffix *-ni̤* marks plural and *-kɛ̤* marks singular. Note that for plural, Nuer has multiple exponence because both *-ni̤* and a H tone mark plural.

```
(218) L tonal tree (OBL)     (219) H tonal tree (PL)     (220) HL tonal tree (PL)
       L                            H                            H L
       |                            |                            \/
       o                            o                            o
```

In the plural of the nominative case, hybrid and unstable stems mostly get a H tone on the stem. Some of these two kinds of nouns, however, are specified for the HL tonal tree allomorph in (220). Because plural stems are derived from singular stems, I assume either a H or a HL tone link to the singular stems. For example in (221), the singular stem is hybrid because it has a L tonal tree. It becomes plural by linking the HL tonal tree allomorph to the stem. An example of this process would be the singular form of *rɔ̀aːm* 'sheep' which gets the plural form with a HL tone *rɔ̂ːm*.

(221) Association of HL tonal tree (tonal allomorph of PL H)

```
L  HL
|   |/
o   o
   ,'
σ_HL
```

Note that the HL tone in the plural cannot simply be the addition of a H tone to the singular tone because other nouns have a H tone in the singular which become HL in the plural. An example is the singular form of 'tribe' *dó̤ːr* which has the plural form *dʊ̂ˑr*.

9.2 Overview of inflection

The defective affix material interacts with defective stem material at different strata. There are three levels of evaluation: stem, word, and phrase level as standardly assumed in Stratal OT – see section 8.3 of the previous chapter. The root contains the lexical representations with the three different autosegmental structures which were given in (215)–(217) above. The plurals are derived from the singular. For the oblique case, a singular stem serves as the input when deriving the singular oblique form. Similarly, the plural is the input for the plural oblique form. If instead, the oblique case in the plural were derived from the singular oblique stems, the wrong surface tones would appear. Take for example the forms for 'dryness'. The singular oblique form has a L with a H suffix *rɛ̀ˑt̪-kɐ̤́*. The plural has a H tone, *rɛ̤́ˑt̪*, and the oblique plural form adds a L-toned suffix *rɛ̤́ˑd̪-nì̤*. If the oblique plural form were derived from the oblique singular form, it would make the wrong predictions for the surface tones because it would incorrectly generate a L-toned form **rɛ̀ˑd̪-nì̤*, or according to OCP-L, **rɛ̀ˑd̪-ní̤*. Instead, the oblique plural form is *rɛ̤́ˑd̪-nì̤*.

An overview of the levels and the exponence is given in tables 9.1–9.2 below. All suffixes are toneless in the input. The plural has two exponents which appear on different levels. The suprasegmental exponent is a H tonal tree with the HL variant which appears on the stem level, and the suffix *-ni̤* which appears on the word level.

At the stem and word levels, the tonal processes of the singular nouns only involve lexical tones and no grammatical tones. Thus, at these strata, such stems go through the evaluation with the same constraint ranking as the plurals, but without grammatical exponence. The effect of the evaluations is that the floating tonal trees of hybrid nouns link to their stems. Nothing changes for stable and unstable stems until the phrase level.

In the inflection of the oblique case, both singular and plural stems get segmental and suprasegmental exponence. For singular stems, the suffix *-kɐ̤* appears with a L tonal tree which floats. For plural stems, only the L tonal tree appears in the inputs of the oblique case at the phrase level, and the suffix *-ni̤* appears earlier, at the word level. When simply the nominative forms are derived, the stems go through the phrase level but without the oblique exponents. This is illustrated in Table 9.2.

Level	Singular	Plural	Output
Stem level	Ø	H tonal tree	Nominative case
Word level	Ø	*-ni̤*	Nominative case
Phrase level	*-kɐ̤*; L tonal tree	L tonal tree	Oblique case

Table 9.1: Strata and exponence (tonal and suffixal) for oblique case.

Level	Singular	Plural	Output
Stem level	Ø	H tonal tree	Nominative case
Word level	Ø	*-ni̤*	Nominative case
Phrase level	Ø	Ø	Nominative case

Table 9.2: Strata and exponence (tonal and suffixal) for plural in the nominative case.

The main idea of the analysis is that the tonal structures of stems make it either possible or impossible for grammatical tones to link to them. The tone of the stable stems can never be overwritten by grammatical tones because it is linked to the stem syllable in the input. The hybrid and the unstable stems, however, have floating lexical tones in the input so that grammatical tones are free to link to their stems at different strata.

Moreover, floating tones which fail to link to a segment are never deleted across levels, which has the following essential outcomes: Concerning plurals, the H tonal tree at the stem level fails to link to stable nouns because they are already tonally specified in the input. At the word level where the suffix *-ni̤* appears, this H tonal tree has been transferred from the stem level and can freely link to *-ni̤*. This accounts for why stable stems get the H-toned *-ní̤* in the nominative. For the other stems, when *-ni̤* appears, there is no grammatical tone in the plural nominative because it linked to the stem syllable *earlier*, i.e., at the stem level. Therefore, the suffix remains toneless. Due to markedness constraints, it cannot get a surface tone at this level. At the phrase level, all plural stems have a specified tone which is grammatical or lexical. For hybrid stems and unstable plurals, the L tonal tree for oblique case can now link to the suffix *-ni̤* which is toneless from the word level. This is not possible for the stable stems because their suffix *-ní̤* has already been specified for a H tone. Therefore, they stay the same as in the nominative.

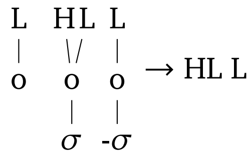
In the oblique case of the singular, stable and hybrid stems have a linked tone in the input at the phrase level. Here, the L tonal tree and *-kɐ̤* appear simultaneously, and this suffix surfaces with a L tone. This is not possible for unstable singular stems since they are not linked to a tone in the input, and both the suffix and stem cannot get a tone. Because there is a preference for the stem to get a tone, the oblique L tonal tree links to the stem instead of the suffix. The entire toneless suffix is deleted including the onset (/k/ in *-kɐ̤*). The fact that the consonant and not just the vowel is deleted is motivated by the phonology in Nuer which bans complex codas in the stems. As was shown in see section 7.2.2, the onset consonants of the suffixes are deleted when the stem contains a liquid consonant. If only the vowel of the suffixes were deleted (apocope), this would result in ungrammatical stems which do not appear in Nuer (e.g., *dɔ̤̀ːrk tribe\OBL instead of the correct output *dɔ̤̀ːr*).

9.2.1 Position and effect of floating tones

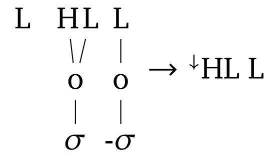
Floating tones are generally inserted to the right of a syllable in a suffix position. Both the plural H and the oblique L tonal trees are inserted after the stem syllable. The same goes for H tone epenthesis. In sequences of adjacent L-toned syllables, a H tone is inserted after the L-toned syllable it wants to target, see e.g. (224) below.

Concerning the output effect of floating tones, I assume that only floating L tones create downstep (see Pulleyblank 1986). Other floating tonal material such as floating H/HL tones or L tonal trees do not induce downstep. Such tones do not have a phonetic effect on surrounding tones and are assumed to be deleted before a sequence is pronounced. For example, the floating tonal tree in (222) has no effect on the output. This means that the L tonal tree of oblique case does not induce downstep in cases where the entire tree remains floating, such as in stable plural nouns. On the other hand, the floating L tones in (223) and (224), which are not associated to any material, i.e., a root node or a syllable, induce downstep on the following H tones.

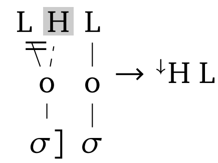
(222) No downstep



(223) Downstep

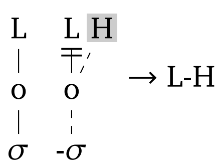


(224) Downstep



Phonetically, the downstep effect of floating L tones on a H tone is only possible to detect in a sentence-initial position or sentence-medially where no other L tones precede. The reason for this is that Nuer has final lowering and automatic downstep – see chapter 3, where linked L tones lower following H tones. Thus, in examples such as (225), the H tone on the suffix is lower compared to a H tone which does not follow a L tone. However, this sequence is not transcribed with a downstep but as L-H. The reason for this is that it is not clear whether it is lowered by the linked L tone of the stem, the unlinked L tone, or because it is in a final position. Thus, only examples such as (223) and (224) above are transcribed with a downstep, since the lowering of the H tones cannot have another source.

(225)



9.2.2 Plural inflection

Table 9.3 below shows the tone processes for L-toned nouns in the nominative case. There are two kinds of hybrid nouns: the more frequent one, which takes a plural H tonal tree, and the less frequent one, which takes a HL tonal tree. At the stem level, the inputs are singular roots with the plural tone exponents. These tones appear with a root node and the HL tonal tree. For the stable stem, the H tonal tree remains floating because an association would lead to either a derived contour tone or the lexical tone would have to be deleted. High-ranked constraints militate against these outcomes. Therefore, the output is the same as the input. For the hybrid stem, the plural H tonal tree can link to the stem without violating any faithfulness constraints. The same applies to the stem with the HL tonal tree. Since this contour tone is a unit, it links to the stem just as the H tonal tree does. It is more important for right-edge tones to link to a syllable than for tones in other positions. Thus, the linking between the stem and the plural H tonal tree is preferred over a linking between the lexical L tonal tree and the stem syllable.

The unstable stem also gets a tone at the stem level because the plural tones have a root node which unstable stems lack. The outputs for hybrid and unstable stems are therefore monosyllabic stems with a plural H or HL surface tone. Note that if the stem tones were H or HL, the very same processes would apply. That is, the H or HL plural tonal trees would link to the stems. If a hybrid stem has a HL lexical tonal tree, it does not matter for the output whether the lexical tonal tree or plural HL tonal tree link to the stem. However, the model proposed here predicts that the HL tonal tree will always link to the stem.

At the word level, the toneless suffix *-ni̤* appears in the input. Because floating tones are not deleted across levels, the stable noun has a H tonal tree from the stem level. This permits the plural H tonal tree to link to the suffix creating a disyllabic plural form in the nominative: *gwàk-ní̤* 'foxes'. If the stem tone has a H or HL tone, these tones will become L because Nuer has a high ranked constraint against more than two H tones at this level.

For the other stems at the word level, there are no floating tones which can link to the toneless syllables without violating well-formedness constraints of autosegmental structures such as *X (No crossing of association lines). Also, high ranked constraints militate against tone spreading and tone insertion. The best solution is therefore that the suffix remains toneless. These intermediate outputs are stems with a H or a HL tone and a toneless suffix: *lá̤ːk-ni̤* 'dreams', *rɔ̂ːm-ni̤* 'sheep', and *wɛ̤́ˑŋ-ni̤* 'eyes'.

At the phrase level, there are no exponents in the nominative case. For the stable stem, nothing can improve the input because it has two syllables with linked tones: *gwàk-ní̤* fox-PL. The hybrid and unstable stem, on the other hand, have a stem with linked H or HL tones, and a toneless *-ni̤*. There are no floating tones which can link to this suffix. High ranked constraints prevent *-ni̤* from getting a tone through tone spreading or tone insertion. Thus, the whole suffix is deleted. The outputs are monosyllabic stems, e.g., *lá̤ːk* dream\PL, *rɔ̂ːm* sheep\PL, and *wɛ̤́ˑŋ* eye\PL.

<table>
<tr><th>Level</th><th>Stable</th><th>Hybrid</th><th>Hybrid$_{HL}$</th><th>Unstable</th></tr>
<tr><td>Root Singular</td><td>L
|
o
|
σ</td><td>L
|
o

σ</td><td>L
|
o

σ$_{HL}$</td><td>L

σ</td></tr>
<tr><td>Stem level Input
Plural H(L) tonal trees</td><td>/gwàk$^{\mathrm{H}}$/
L H
| |
o o
|
σ</td><td>/$^{\mathrm{L}}$la̤ːk$^{\mathrm{H}}$/
L H
| |
o o

σ</td><td>/$^{\mathrm{L}}$rɔːm$^{\mathrm{HL}}$/
L HL
| \/
o o

σ$_{HL}$</td><td>/$^{\mathrm{L}}$wɛ̤ˑŋ$^{\mathrm{H}}$/
L H
|
o
/
σ</td></tr>
<tr><td>Stem level Output
Plural H(L) tonal trees
link to hybrid
and unstable stems</td><td>gwàk
L H
| |
o o
|
σ</td><td>lá̤ːk
L H
| |
o o
/
σ</td><td>rɔ̂ːm
L HL
| |/
o o
/
σ$_{HL}$</td><td>wɛ̤́ˑŋ
L H
|
o
/
σ</td></tr>
<tr><td>Word level Input
-ni̤</td><td>/gwàk-ni̤/
L H
| |
o o
|
σ -σ</td><td>/lá̤ːk-ni̤/
L H
| |
o o
/
σ -σ</td><td>/rɔ̂ːm-ni̤/
L HL
| \/
o o
/
σ -σ</td><td>/wɛ̤́ˑŋ-ni̤/
L H
|
o
/
σ -σ</td></tr>
<tr><td>Word level Output</td><td>gwàk-ní̤
L H
| |
o o
| ¦
σ -σ</td><td>lá̤ːk-ni̤

(No change from input)</td><td>rɔ̂ːm-ni̤</td><td>wɛ̤́ˑŋ-ni̤</td></tr>
<tr><td>Phrase level Input
(No exponents)</td><td>/gwàk-ní̤/
L H
| |
o o
| |
σ -σ</td><td>/lá̤ːk-ni̤/
L H
| |
o o
/
σ -σ</td><td>/rɔ̂ːm-ni̤/
L HL
| |/
o o
/
σ -σ</td><td>/wɛ̤́ˑŋ-ni̤/
L H
|
o
/
σ -σ</td></tr>
<tr><td>Phrase level Output

Deletion of
toneless -ni̤</td><td>gwàk-ní̤
fox-PL
L H
| |
o o
| |
σ -σ</td><td>lá̤ːk
dream\PL
L H
| |
o o
/
σ</td><td>rɔ̂ːm
sheep\PL
L HL
| |/
o o
/
σ</td><td>wɛ̤́ˑŋ
eye\PL
L H
|
o
/
σ</td></tr>
</table>

Table 9.3: Overview of stratal tone associations in the plural nominative case.

Table 9.4 shows the inflection of the plural oblique case. There are no changes from Table 9.3 except for the phrase level. Here, the L tonal tree appears in the input for the plural stems. The stable noun already has tones linked to the stem and the suffix so that the L tonal tree cannot link to any syllable and remains floating. Therefore, the output is the same as for the phrase level of the nominative case: *gwàk-ní̤* fox-OBL.PL. For the hybrid and unstable stems, there is now a L tonal tree which can link to toneless *-ni̤*. These outputs have a H or HL stem with a L-toned suffix: *lá̤ːk-nì̤* dream\PL-OBL.PL, *rɔ̂ːm-nì̤* sheep\PL-OBL.PL, and *wé̤ˑŋ-nì̤* eye\PL-OBL.PL.

Level	Stable	Hybrid	Hybrid$_{HL}$	Unstable
Root Singular	L | o | σ	L | o σ	L | o σ_{HL}	L σ
Stem level Input H(L) tonal tree (PL)	/gwàk^H/ L H | | o o | σ	/^Lla̤ːk^H/ L H | | o o σ	/^Lrɔːm^HL/ L HL | \\/ o o σ_{HL}	/^Lwe̤ˑŋ^H/ L H | o / σ
Stem level Output H(L) tonal tree (PL) links to hybrid and unstable stems	gwàk L H | | o o | σ	lá̤ːk L H | | o o / σ	rɔ̂ːm L HL | |/ o o / σ_{HL}	wé̤ˑŋ L H | o / σ
Word level Input *-ni̤*	/gwàk-ni̤/ L H | | o o | σ -σ	/lá̤ːk-ni̤/ L H | | o o / σ -σ	/rɔ̂ːm-ni̤/ L HL | \\/ o o / σ -σ	/wé̤ˑŋ-ni̤/ L H | o / σ -σ
Word level Output	gwàk-ní̤ L H | | o o | | σ -σ	lá̤ːk-ni̤	rɔ̂ːm-ni̤	wé̤ˑŋ-ni̤
		(No change from input)		
Phrase level Input L tonal tree (OBL)	/gwàk-ní̤/ L H L | | | o o o | | σ -σ	/lá̤ːk-ni̤ / L H L | | | o o o / σ -σ	/rɔ̂ːm-ni̤/ L HL L | |/ | o o o / σ -σ	/wé̤ˑŋ-ni̤/ L H L | | o o / σ -σ
Phrase level Output Linking between the L tonal tree and toneless *-ni̤*	gwàk-ní̤ fox-OBL.PL L H L | | | o o o | | (...) σ -σ	lá̤ːk-nì̤ dream-OBL.PL L H L | | | o o o / | (...) σ -σ	rɔ̂ːm-nì̤ sheep-OBL.PL L HL L | |/ | o o o / / (...) σ -σ	wé̤ˑŋ-nì̤ eye-OBL.PL L H L | | o o / | (...) σ -σ

Table 9.4: Overview of stratal tone associations in the plural oblique case.

The advantage of the serial derivation is that it captures why the suffix *-n̤i̤* appears as L-toned in some cases, i.e., with hybrid and unstable nouns like *rɛ́ˑd̪-n̤ì̤* dryness\PL-OBL.PL, but with a H tone with stable nouns such as *kè̤ˑr-í̤* lines-OBL.PL. The different tones on *-n̤i̤* arise because the plural marker is defective and appears as a suprasegmental and a segmental marker at separate levels. The output relies on the timing of the associations. When *-n̤i̤* manages to get a tone early, i.e., the H tonal tree at the word level, it will fail to get the L tonal tree at the phrase level. On the contrary, when *-n̤i̤* fails to get the H tonal tree at the word level, it remains toneless and gets its tonal specification later at the phrase level from the L tonal tree. This approach allows for just one lexical specification of this suffix, a toneless *-n̤i̤*. I argue that this approach is favorable compared to having two lexical specifications of *-n̤i̤*: one H-toned and one L-toned.

9.2.3 Singular nouns

For the singular nouns, the mechanism is the same as in the plural. The main difference is that there are no exponents before the phrase level, where the oblique case is derived. An overview of the tone processes of the singular nouns in the nominative is given below in Table 9.5. The roots have lexical tones and are stable, hybrid, and unstable nouns. The table shows roots specified for L and H tones which are inputs at the stem level. At the stem and word level, the only change from input to output is that the lexical H and L tonal trees of the hybrid nouns link to the stem syllable. This is not possible for the unstable stem because, at both the stem and word level, the stem lacks a root node. The unstable stems remain unlinked to a tone until the phrase level because of a high-ranked constraint militating against insertion of a root node. This constraint equally militates against the insertion of a tonal tree since they have a root node. For the stable stems, no improvements are possible between the stem and phrase level because the stem already has a lexical tone linked to the stem syllable.

At the phrase level, there are a few processes to observe. The H-toned roots are discussed first in the three right-most columns of Table 9.5. The preceding auxiliaries are shown to the left with a square bracket. For the stable and hybrid stems with a lexical H tone, no changes are made from input to output. Examples of such sentences are: *c̤é̤ gá̤ˑc nɛ̀ˑn* 'I have seen the belt', and *c̤é̤ wɔ̤́ˑk nɛ̀ˑn* 'I have seen the shoulder'. For the H-toned unstable stem, there is no root node for the lexical H tone to associate to. The solution is to insert a root node which makes it possible for the stem to get a tonal specification. This is only possible at the phrase level where there are no other floating tonal trees. The output is a monosyllabic H-toned noun. For example *c̤é̤ d̪ó̤ːl nɛ̀ˑn* boy 'I have seen the boy'.

The same processes apply to the L-toned roots in the left-most columns. At the phrase level, the crucial differences are that the lexical L tones violate the OCP-L when preceded by a L-toned possessed noun (indicated by the square bracket). To avoid such violations, H tones are inserted in these configurations. They always appear to the right of the linked tones they target. The unstable noun does not have a tone in the input. Therefore, by inserting a root node, the stem can link to the H tone without violating any faithfulness constraints for tone. The output is *cɛ̀ ꜜwáŋ nɛ̂ˑn* '(S)he has seen an eye', where the floating L tone creates a downstep on the H tone.

For the phrase-level constructions with the stable and hybrid nouns, both the preceding syllable and the nouns have a specified L tone in the input. Thus, delinking a L tone and linking the H tone will violate tonal faithfulness constraints in both stable and hybrid classes. The preference is to link the H tone to the syllable preceding the noun because of a faithfulness constraint which protects the linked right-most tone of a p-phrase. The output of /L L…/ is [ꜜH L]. An example of such a sentence is *ꜜcɛ́ˑ gwàk nɛ̂ˑn* '(S)he has seen the fox' and ꜜcɛ́ˑ rɔ̀aːm nɛ̂ˑn – see section 10.2.3 concerning the HL tone on the verb. The delinked L tone creates a downstep on the epenthesized H tone of the auxiliary. The phonetic realization is a M tone.

Level	Stable L	Hybrid L	Unstable L	Stable H	Hybrid H	Unstable H
	/gwàk/ 'fox'	/ᴸrɔaːm/ 'sheep'	/ᴸwaŋ/ 'eye'	/ga̤ˑc/ 'belt'	/ᴴwɔ̤ˑk/ 'shoulder'	/ᴴd̪o̤ːl/ 'boy'
Stem level Input	L | o | σ	L | o σ	L σ	H | o | σ	H | o σ	H σ
Stem level Output	L | o | σ gwàk	L | o ¦ σ rɔ̀aːm	L σ waŋ	H | o | σ ga̤ˑc	H | o ¦ σ wɔ́ˑk	 σ d̪oːl
Word level	vacuous processes					
Phrase level Input	L L | | o o | | σ]σ	L L | | o o | | σ]σ	L L | o | σ]σ	H H | | o o | | σ]σ	H H | | o o | | σ]σ	H H | o | σ]σ
Phrase level Output H tone epenthesis	ꜜcɛ́ˑ gwàk … PFV-3SG fox L H L o o σ] σ	ꜜcɛ́ˑ rɔ̀aːm … PFV-3SG sheep L H L o o σ] σ	cɛ̀ ꜜwáŋ … PFV-3SG eye L L H o o σ] σ	cɛ̤́ ga̤ˑc … PFV-1SG belt H H o o σ] σ	cɛ̤́ wɔ̤ˑk … PFV-1SG shoulder H H o o σ] σ	cɛ̤́ d̪ó̤ːl … PFV-1SG boy H H o o σ] σ

Table 9.5: Overview of stratal tone associations in the singular nominative case.

The fact that the unstable stems remain with a floating lexical tone until the phrase level captures the paradox of the data. Namely, that on the one hand, these stems behave as specified for lexical tone because they surface with a H, L, or HL in the nominative singular. On the other hand, they behave as toneless because the grammatical and epenthesized tones can freely link to their stems. In order for this to happen, lexical tone linking has to be postponed until the very end of the evaluations. It is mandatory that (i) tones do not link to the unstable stems until the phrase level, and (ii) floating tones are not deleted between strata. That is, they need to be available to link to the stem in case no other tone can.

Table 9.6 below shows the inflection of the same nouns for the oblique case. At the stem and word level, there are no differences from the nominative case in Table 9.5 above. At the phrase level, the H-toned roots are discussed first in the three right-most columns in Table 9.6. The exponence for the oblique case appears in the input: the toneless suffix *-kɛ̤* and the oblique tone L. For the stable and hybrid stems with a lexical H tone, there is now a toneless suffix and a floating tone which are free to link: *bîɛl gá̤ˑj-kɛ̤̀* color belt-OBL.SG (i.e. 'the color of the belt') and *míɛˑm wṳ́ˑ-kɛ̤̀* hair shoulder-OBL.SG. For the H-toned unstable stem, on the other hand, there are now two toneless syllables but only one tonal tree. It is not possible for this L tonal tree to link to both syllables, and it links to the stem-syllable. Because of a high-ranked constraint against toneless syllables, the best option is to delete the whole suffix rather than inserting a new root node, a tonal tree, or spreading the existing tones onto the toneless suffix. Deleting the stem and keeping the suffix is excludes because of a faithfulness constraint against deletion of left-most segments of a prosodic word, i.e., the stem. The output is a monosyllabic noun: *míɛˑm d̪ʊ̀l* hair boy\OBL.SG 'the hair of the boy'.

The same processes apply to the L-toned roots in the left-most columns. At the phrase level, the crucial differences are that the L tonal tree of the oblique case cannot link to the stems because they would violate OCP-L, and H tones are therefore inserted in these configurations. An important detail here is that the H tones come without a root node. This is crucial for the unstable stems. For the stable and hybrid stems, the H tones link to the toneless suffixes by taking the root nodes of the oblique marker and deleting the association between it and the root node. This does not violate any high ranked faithfulness constraints because the suffix was not specified for tone in the input. The result is a H-toned suffix *-kɛ̤́*, which appears with L-toned stems. In addition, OCP-L violations arise due to the adjacent L-toned possessum nouns (shown with square brackets). A H tone is also inserted on the possessum stems to avoid violating the OCP-L. As mentioned above for the nominative case, it is not inserted on the possessed nouns because of the faithfulness constraint which preserves the right-most linked tone of a p-phrase. The output is two times H tone epenthesis: /cɔ̤̀a̤ː gwàk-ɛ̤/ → [ꜜcɔ̤́a̤ː gwàk-ɛ̤́] bone fox-OBL 'the bone of the fox' and /cɔ̤̀a̤ː rɔ̀ːm-kɛ̤/ → [ꜜcɔ̤́a̤ː rɔ̀ːm-kɛ̤́] bone sheep-OBL 'the bone of the sheep'. These H tones appear in a suffix position, i.e., to the right of the syllable which is targeted. The delinked L tones create a downstep on the epenthesized H tones on the possessum nouns.

For the unstable stems, the nouns shown are also adjacent to a L-toned possessum noun.

There are two toneless syllables here. If the H tone would be a H tonal tree, it would be expected that, e.g., it would link to the suffix, and the L tonal tree would link to the stem, as was the case for stable and hybrid stems. This would make the wrong predictions because the output of unstable nouns is a monosyllabic H-toned stem, not a disyllabic noun. This indicates that H tone epenthesis is a floating tone instead of a tonal tree, i.e., lacking a root node. This way, only one syllable of the unstable noun will get the chance to link to a tone. Because of the constraint rankings, this has the consequence that only the stem syllable receives a tone and will survive in the output deleting the suffix *-kḛ*. The linking between the H tone and the stem syllable is done by using the root node of the oblique marker while the association between the L tone and its node is deleted. The output is a phonetic M-toned stem when oblique unstable stems are adjacent to a L tone. The possessum noun remains L-toned: /cɔ̰̀a̰ː ^{L}waŋ/ → [cɔ̰̀a̰ː ↓wáŋ] bone eye\OBL 'the bone of the eye'.

<table>
<tr><th>Level</th><th>Stable L</th><th>Hybrid L</th><th>Unstable L</th><th>Stable H</th><th>Hybrid H</th><th>Unstable H</th></tr>
<tr><td></td><td>/gwàk/
'fox'</td><td>/^{L}rɔaːm/
'sheep'</td><td>/^{L}waŋ/
'eye'</td><td>/gá̰ˑc/
'belt'</td><td>/^{H}wɔ̰ˑk/
'shoulder'</td><td>/^{H}d̪o̰ːl/
'boy'</td></tr>
<tr><td>Stem level
Input</td><td>L
|
o
|
σ</td><td>L
|
o

σ</td><td>L

σ</td><td>H
|
o
|
σ</td><td>H
|
o

σ</td><td>H

σ</td></tr>
<tr><td>Stem level
Output</td><td>L
|
o
|
σ
gwàk</td><td>L
|
o
¦
σ
rɔ̀aːm</td><td>L

σ
waŋ</td><td>H
|
o
|
σ
gá̰ˑc</td><td>H
|
o
¦
σ
wɔ́ˑk</td><td>H

σ
d̪oːl</td></tr>
<tr><td>Word level</td><td colspan="6">vacuous processes</td></tr>
<tr><td>Phrase level
Input:
L tonal
tree, -kḛ</td><td>L L L
| | |
o o o
| |
σ]σ -σ</td><td>L L L
| | |
o o o
| |
σ]σ -σ</td><td>L L L
| |
o o
|
σ]σ -σ</td><td>H H L
| | |
o o o
| |
σ]σ -σ</td><td>H H L
| | |
o o o
| |
σ]σ -σ</td><td>H H L
| |
o o
|
σ]σ -σ</td></tr>
<tr><td>Phrase level
Output</td><td>↓cɔ̰́a̰ː gwàk-ḛ́
bone fox-OBL</td><td>↓cɔ̰́a̰ː rɔ̀ːm-kḛ́
bone sheep-OBL</td><td>cɔ̰̀a̰ː ↓wáŋ
bone eye\OBL</td><td>bîɛl gá̰ˑj-kḛ̀
color belt-OBL</td><td>míɛˑm wṵ́-kḛ̀
hair shoulder-OBL</td><td>míɛˑm d̪ɔ̀l
hair boy\OBL</td></tr>
<tr><td>H tone
epenthesis</td><td>L H L L H
o o o
σ] σ -σ</td><td>L H L L H
o o o
σ] σ -σ</td><td>L L L H
o o
σ] σ</td><td>H L H L
o o o
σ] σ -σ</td><td>H H L
o o o
σ] σ -σ</td><td>H H L
o o
σ] σ</td></tr>
</table>

Table 9.6: Overview of stratal tone associations of the singular oblique case.

9.3 Constraints

The constraints for this analysis refer to the autosegmental structures of tones – see also section 8.4 for background theory. Since Nuer has both floating tones and floating tonal trees, the constraints which refer to both of these tones use 'τ' as an agnostic term. Constraints are gradient and can induce more than one violation marks.

A few constraints for this analysis refer to prosodic structure. As was mentioned in section 5.5.3, I assume that each lexical word, including affixes, forms a prosodic word (see Selkirk 1995, among others). At the phrase level, there is a prosodic difference between sequences such as (226) – repeated from (111) in chapter 5 and (227) – repeated from (195) in chapter 7. In the former, there is a pause between the subject and the predicate, while in the latter, there is no pause between the two nouns. I propose that such pauses indicate a p-phrase boundary. Thus, lexical words which have a pause between them such as (226) form their own p-phrase, while constructions with a possessum and possessor noun, such as (227), form one p-phrase.

(226) ((kè̤ːr)$_{\omega}$)$_{\phi}$ ((gwà-ɛ̀ː)$_{\omega}$)$_{\phi}$
line good-3SG
'The line is good.'

(227) /bîɛl kè̤ˑr-ɘ̤/
((bîɛl)$_{\omega}$ (kè̤ˑr-ɘ̤́)$_{\omega}$)$_{\phi}$
color line-OBL.SG
'the color of the line'

In Nuer, grammatical tones generally want to link to a syllable. It is one of the essential properties of the analysis that stems surface with grammatical tones instead of lexical tones. Grammatical tones in inflection appear as suffixes to the right of the stems. The preference of floating grammatical tones over floating lexical tones is captured by a high ranking of the markedness constraint $\tau]_{\omega}\!\rightarrow\sigma$ in (228). This constraint refers to tones and tonal trees positioned final in a prosodic word. At the phrase level, this constraint refers to the p-phrase domain $\tau]_{\phi}\!\rightarrow\sigma$. If a candidate has two floating tones, a lexical tone to the left, and a grammatical tone to the right, this constraint will favor a linking between the grammatical tone and the stem. This is exactly what happens with unstable stems in the oblique case, and hybrid stems in the plural. Namely, they get a grammatical tone which links to the stem instead of the floating lexical tone.

(228) $\begin{array}{c}\tau]_{\omega}\\ \downarrow\\ \sigma\end{array}$ (modified from Trommer 2011)

Assign a violation mark for every Prosodic Word-final tone/tonal tree (τ) which is not linked to a syllable.

For toneless syllables, the linking to a floating tone is straightforward because they need a tonal specification in the output. Concerning syllables which are already specified for tone, they only link to a floating tone in a few cases (i.e., when violating high-ranked markedness constraints such as the OCP-L). This is regulated by a high ranking of two markedness constraints against different association lines in syllables which are versions of the constraint *DIFFAL$_\sigma$ proposed by Zimmermann (2015), which refers to different association lines in syllables.

First, the constraint *T T \ ⁄ o in (229) militates against pair of tones which are linked to the same root node through different association lines, i.e., a tone with an epenthetic association line (dashed) and tone with an underlying association line (solid).

(229)
```
*T T
  \ '
   o
```
Assign a violation mark for every pair of tones T_1 and T_2 associated to a root node, where T_1 and T_2 have different association line types (±epenthetic).

An inserted H tone cannot link to a syllable specified for tone unless that input tone is delinked because it would violate *T T \ ⁄ o. Thus, the structure in (230) violates this constraint because the root node is linked to two tones with different association lines. This kind of violation can be avoided if the solid association line were to be delinked as in (231).

(230)
```
*H  L
  ` /
   o
   |
   σ
```

(231)
```
 H  L
  ` ≠
   o
   |
   σ
```

The second constraint against different association lines is *o o \ ⁄ σ in (232) which militates against every pair of root nodes which are linked to the same syllable through different association lines; i.e., a root node with an epenthetic association line (dashed) and another one with an underlying association line (solid).

(232)
```
*o o
  \ '
   σ
```
Assign a violation mark for every pair of root nodes o_1 and o_2 associated to a syllable, where o_1 and o_2 have different association line types (±epenthetic).

The constraint in (232) is violated by the structure in (233) below, where the syllable is linked to a root node with an input association line and a root node with an epenthesized association line. The other two structures in (234)–(235) do not violate *o o \ ⁄ σ since the syllable is linked to root nodes with the same association line (either both input association lines or both epenthetic ones).

(233)
```
*T   T
 |   |
 o   o
 |  ,'
 σ
```

(234)
```
 T   T
 |   |
 o   o
 ¦  ,'
 σ
```

(235)
```
 T   T
 |   |
 o   o
  \ /
   σ
```

The constraint $*\mathrm{TT} \rightrightarrows \mathrm{o}$ bans derived unitary tones while the constraint $*\mathrm{oo} \rightrightarrows \sigma$ militates against derived cluster tones, when these derived tones involve one underlying tone. If a more general constraint were used such as *CONTOUR (cf. Yip, 2002), it would wrongly penalize lexical, unitary contour tones in Nuer which are in the input. Both constraints are active on all strata. However, for reasons of simplicity, the stem-level is only showed with $*\mathrm{oo} \rightrightarrows \sigma$ since the essential candidates only violate this constraint.

As was noted, the constraint $*\mathrm{oo} \rightrightarrows \sigma$ does not militate against the type of derived contour tone in (234) above. However, such a candidate would be penalized twice by the constraint DEP| in (236). This constraint militates against association lines which are not in the input and is formally similar to NO-SPREAD(τ, ς) in McCarthy (2000). The sub-versions of this constraint bans insertion of association lines between a root node and a segment, and between a tone and a segment. For reasons of space, the tableaux simply shows DEP| referring to both of these constraints.

(236) DEP|

- i DEP|(σ,o) Assign a violation mark for every pair of syllable σ_1 and root node o_1 in the input which correspond to a syllable σ_2 and root node o_2 in the output, where σ_2 and o_2 are associated, but σ_1 and o_1 are not associated.
- ii DEP|(o,T) Assign a violation mark for every pair of root node o_1 and tone T_1 in the input which correspond to a root node o_2 and tone T_2 in the output, where o_2 and T_2 are associated, but o_1 and T_1 are not associated.

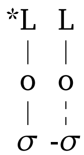
Adjacent L tones arise at the phrase level. Here, the constraint OCP-L is violated when identical L tonal trees are linked to adjacent syllables (237). According to this version of the OCP, adjacent floating L tones do not violate the OCP-L.

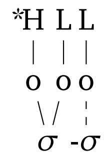
(237) OCP-L

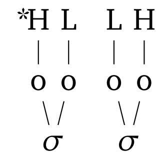
Assign a violation mark for every pair of identical L tonal trees which are adjacent and linked to distinct syllables.

The structures which violate OCP-L are represented below. In (238), the L tonal trees are identical, adjacent, and linked to separate syllables. The same goes for the structures in (239) and (240). The syllables also have a H tonal tree, but since the L tonal trees are adjacent and linked to two different syllables, they nevertheless violate OCP-L once.

OCP-L violations

(238) 

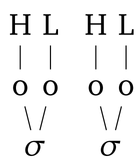
(239) 

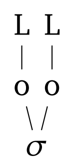
(240) 

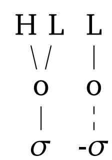
Examples of L tone structures which do not violate OCP-L are presented below. In (241), the syllables are linked to identical L tonal trees, but these L trees are not adjacent. In (242), the L tonal trees are adjacent but linked to the same syllable. A HL#L sequence does not violate OCP-L if the HL tone is a unitary tone since this is a HL tonal tree and not a L tonal tree. Thus, the structure in (243) does not violate OCP-L.

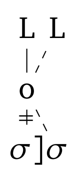
Furthermore, the structures in (244)–(247) do not violate the OCP-L. In (244)–(246) there is only one L tonal tree. In (247), there are two L tonal trees, but one has been delinked from the syllable. Note that the structures in (245) and (246) are considered tone spreading since the root node is linked to two syllables.

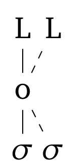
No OCP-L violations

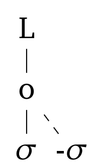
(241) 

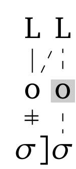
(242) 

(243) 

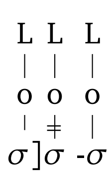
(244) 

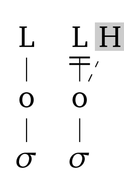
(245) 

(246) 

(247) 

Violations of OCP-L can be avoided by either deleting the association line between a syllable and a L tone as in (248) or by H tone epenthesis as in (249). The former involves adjacent L tonal trees, but the one in the middle has been delinked so there is no pair of L tonal trees which are both adjacent and linked to distinct syllables. OCP-L repairs such as (249) are favored over repairs such as (248) because of the high-ranked constraint $\tau \leftarrow \sigma$ in (250) below which militates against toneless syllables.

(248) 

(249) 

(250) $\overset{\tau}{\underset{\sigma}{\uparrow}}$ (modified from Trommer 2011)

Assign a violation mark for every syllable which is not linked to a tone/tonal tree (τ).

The structure in (249) above violates the constraint DEP-τ in (251) which militates against insertion of a tone or tonal tree which is not in the input. It also violates DEP| in (236) above.

(251) DEP-τ

Assign a violation mark for every output tone/tonal tree (τ) which does not have an input correspondent.

Coming back to the examples of (245)–(246) above, candidates with these structures violate a constraint against tone spreading: $\underset{*}{\text{o}} \leq \overset{\sigma}{\sigma}$ defined in (252). This constraint militates against one root node linked to two syllables. Another constraint against tone spreading is defined in (253) and prohibits L tones from merging: $\underset{*}{\text{L}} \leq \overset{\text{o}}{\text{o}}$. It also makes it impossible for toneless syllables to get a tonal specification through tone spreading. The type of association lines (input or inserted) is irrelevant to both of these constraints.

(252)

```
 *o
 /|
σ σ
```

Assign a violation mark for every root node associated to more than one syllable.

(253)

```
 *T
 /|
o o
```

Assign a violation mark for every tone associated to more than one root node.

The association between a grammatical tone and a stable stem does not violate $\underset{*}{\overset{\text{o}}{\text{o}}} \dashrightarrow \sigma$ when the input association line is delinked as in (254) below. However, this operation is mainly excluded by a high ranking of the constraint MAXτ—σ in (255) which militates against deletion of association lines between a syllable and a tone or tonal tree in the input.

(254)

```
L  H
|  |
o  o
╪ /
σ
```

(255) MAX$\overset{\tau}{\underset{\sigma}{|}}$

Assign a violation mark for every pair of syllable σ_1 and tone/tonal tree τ_1 in the input which correspond to a pair of syllable σ_2 and tone/tonal tree τ_2 in the output, where σ_1 and τ_1 are linked, but σ_2 and τ_2 are not linked.

There is also a more specific version of MAX τ—σ referring to prosodic structures: MAX $\tau]_\phi$–σ in (256). This constraint has the effect of preserving the right-most tone in a p-phrase which is linked to a syllable.

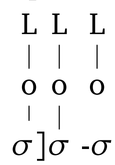
(256) $\text{MAX}\overset{\tau]_\phi}{\underset{\sigma}{|}}$

Assign a violation mark for every pair of syllable σ_1 and tone/tonal tree τ_1 in the input which are p-phrase-final and correspond to a pair of syllable σ_2 and tone/tonal tree τ_2 in the output, where σ_1 and τ_1 are linked, but σ_2 and τ_2 are not linked.

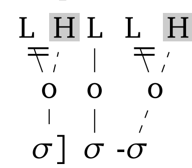
The constraint MAX $\tau]_\phi$–σ penalizes cases where H tone epenthesis would overwrite the possessor noun instead of the possessum noun in constructions with two stable or hybrid nouns. In such cases, both of their stems are linked to a tone in the input. Nevertheless, H tone epenthesis overwrites the tone of the possessum noun, not the tone of the possessor noun as shown in (257). In the input, the medial L tone, linked to the noun *gwàk*, is the right-most tone which is linked to a TBU because the suffix is underlyingly toneless as seen in (258). In the output, H tone epenthesis targets the left-most and right-most syllables in (259). If the stem of *gwàk-ɛ̤* 'fox' would instead be overwritten by H tone epenthesis, it would violate MAX $\tau]_\phi$–σ.

(257) /c̤ɔ̤̀a̤ː gwàk-ɛ̤/
($^{\downarrow}$c̤ɔ̤́a̤ː gwàk-ɛ̤́)$_\phi$
bone fox-OBL
'the bone of the fox'.

(258) Input



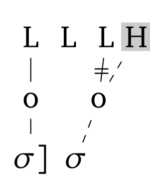
(259) Output



H tone epenthesis is quite straight-forward for constructions with unstable nouns because they are not linked to a tone. First, the inserted H tone goes on the unstable possessor stems without violating faithfulness constraints on tone (260)–(261). Second, the L tone of the possessum noun *c̤ɔ̤̀a̤ː* 'bone' is in fact the right-most linked tone in the p-phrase since the tone of *waŋ* 'eye' is floating in the input. Therefore, a high ranking of MAX $\tau]_\phi$–σ correctly predicts that an underlying tone of the possessum noun must be preserved in constructions where toneless syllables follow, such as unstable nouns.

(260) /c̤ɔ̤̀a̤ː $^{\text{L}}$waŋ/
(c̤ɔ̤̀a̤ː $^{\downarrow}$wáŋ)$_\phi$
bone eye\OBL
'the bone of the eye'

(261)



Contour tones linked to the right-most syllable of a p-phrase are also preserved as a result of MAX $\tau]_\phi$–σ because this constraint is general for all tones in this position. Thus, (262) would also violate this constraint.

(262)
```
L    HL  L
|    |/  |
o    o   o
  ≠/ - -
σ        -σ
```

Another MAX constraint needed is MAX T—o in (263) which militates against deletion of association lines between a tone and a root node. This is violated in structures such as (264), where the association line between the root node and the tone is deleted in the output.

(263) MAX$\overset{T}{\underset{o}{|}}$

Assign a violation mark for every pair of root node o_1 and tone T_1 in the input which correspond to a pair of root node o_2 and tone T_2 in the output, where o_1 and T_1 are associated, but o_2 and T_2 are not associated.

(264)
```
L
ǂ
o

σ
```

There is also a MAX constraint against deletion of either a tone or a tonal tree which was in the input: MAX-τ in (265). This constraint prevents structures such as unstable stems to delete their tone or for hybrid stems to delete their tonal tree, as in (266)–(267).

(265) MAX-τ

Assign a violation mark for every for every τ which does not have an output correspondent.

(266)
```
L     Ø
   →

σ     σ
```

(267)
```
L     Ø
|
o  →

σ     σ
```

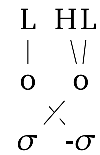
Recall that unstable nouns have a lexical floating tone which lacks a root node. Besides tone spreading, their stems could link to the lexical tone if a root node were inserted. The faithfulness constraint DEP-o militates against this (268). Note that DEP-o is equally violated if a tonal tree is inserted, and in that case, DEP-τ would also be violated since it involves insertion of both a tone and a tonal tree.

(268) DEP-o

Assign a violation mark for every root node in the output which does not have an input correspondent.

In structures such as hybrid plural nouns in (270), there is a toneless suffix at the word level which could link to the lexical tone to the left. Such crossing of association lines, however, violates *X in (269).

(269) NoCrossing (*X) (Yip, 2002)
Assign a violation mark for every pair of association lines which are crossed.

(270) 

The analysis uses two versions of a faithfulness constraint against vowel deletion in (271) – (272). The latter bans deletion of vowels which are left-most in a prosodic word. Recall that toneless suffixes are deleted at the phrase level. When unstable stems get a toneless suffix, which form a prosodic word, only one of these syllables can get a tone and survive in the output (273). It would not be a welcoming result if the suffix–vowel survived but the stem–vowel did not.[1] Note that the structures shown in the tableaux in this chapter are represented as syllables. Since each syllable in Nuer contains a vowel, the representation $/_{\omega}(\sigma\text{-}\sigma)/ \rightarrow {}_{\omega}(\sigma\text{-}\emptyset)$ in (273) violates MAX-V once.

(271) MAX-V
Assign a violation mark for every input vowel without an output correspondent.

(272) MAX_{ω}[V
Assign a violation mark for every input vowel at the left edge of a prosodic word without an output correspondent.

(273) $/_{\omega}(\sigma\text{-}\sigma)/ \rightarrow {}_{\omega}(\sigma\text{-}\emptyset)$
/d̪ʊ̀l-kɛ̤̀/ → d̪ʊ̀l
boy-OBL.SG boy\OBL.SG

Candidates which delete the whole suffix instead of just the vowel are preferred because of the markedness constraint *COMPLEXCODA (*CC]_{σ}) in (274) which is undominated in Nuer.

(274) *COMPLEXCODA(*CC]_{σ}) (Kager, 1999)
Assign a violation mark for every complex coda.

The markedness constraint *CC]_{σ} penalizes nouns where only the vowel is deleted such as **lá̤ːkn* in (275) instead of *lá̤ːk*. The high raking of this constraint is supported by the data since Nuer does not have complex codas. Also, there is already consonant deletion in suffixes which

[1] Since this constraint does not refer to moras, I assume that short, mid, and long vowels which are deleted from the input equally violate MAX-V.

attach to stems with a liquid or a nasal – see section 7.2.2. For convenience, only one tableau will show segmental material with this constraint.

(275) /lá̤ːk-ni̤/ → [lá̤ːk] 'dreams'

Finally, in addition to the restriction against adjacent L tones at the phrase-level, there is a constraint referring to H tones. Recall that stable nouns get a H-toned *-ní̤* in the plural. If the stem has a H or HL tone, it will simplify to L – see Table 7.8 in chapter 7. This is regulated by the constraint in (276) which requires singularity of a prosodic head (cf. Hyman 2006). The version of this constraint penalizes prosodic words with more than one H tone: CULM(INATIVITY)-H_ω. CULM-H is active at the word level where *-ní̤* is added to the stem. At other levels, I assume it is low ranked.

(276) CULMINATIVITY-H_ω (CULM-H)
Assign a violation mark for every prosodic word linked to more than one H tone.

9.4 Rankings

The rankings of the three strata are discussed in (277)–(279) below.[2] Generally in the grammar of Nuer, toneless syllables need a tonal specification, however, they never get a tone through tone spreading. Thus, at all levels, the constraints *X, $\underset{*}{\text{o}} \leq \overset{\sigma}{\sigma}$, and $\underset{*}{\text{T}} \leq \overset{\text{o}}{\text{o}}$ are ranked higher, or at the same level as $\tau \leftarrow \sigma$.

At the stem and word level, floating tones want to link to a syllable, but not if they overwrite an existing tone by delinking it, or if they create a contour tone. At the stem level, the three constraints MAXτ—σ, $\underset{*}{\overset{\text{o}}{\text{o}}} \geqq \sigma$ and $\underset{*}{\overset{\text{T}}{\text{T}}} \geqq \text{o}$ are ranked above $\tau]_\omega\!\rightarrow \sigma$. At both the stem and word levels, $\tau \leftarrow \sigma$ and $\tau]_\omega\!\rightarrow \sigma$ are crucially ranked above DEP| at these levels so that floating tones which are right-most in the prosodic word are able to link to toneless syllables.

Moreover, unstable nouns cannot get a tone unless the inputs have a floating grammatical tonal tree. Their stem vowels can also never be deleted. This is predicted by the dominance of DEP-o and MAX-V over $\tau \leftarrow \sigma$. A low ranking of DEP-o would falsely generate outputs where unstable stems get a lexical tone too early and cannot link to grammatical tones.

(277) Stem level ranking

$$\text{MAX}\overset{\tau}{\underset{\sigma}{|}}\ \text{DEP-o}\quad \overset{*\text{o}\ \ \text{o}}{\underset{\sigma}{\backslash\,/}}\quad \overset{*\text{T}\ \text{T}}{\underset{\text{o}}{\backslash\,/}}\quad \text{MAX-V}\quad \text{DEP-}\tau\quad \text{MAX}\overset{\text{T}}{\underset{\text{o}}{|}}\ \text{MAX-}\tau \gg \overset{\tau}{\underset{\sigma}{\uparrow}}\quad \overset{\tau]_\omega}{\underset{\sigma}{\downarrow}} \gg \text{DEP}|$$

[2] The four constraints $*\text{CC}]_\sigma$, *X, MAX_ω[V, and OCP-L are only shown at the phrase level where they are essential for the evaluated candidates, but theoretically they are also active at the stem and word level. Similarly, the tableaux for the stem-levels are not shown with the constraint in (229) against different association lines on root nodes since the relevant candidates do not violate this constraint; and the constraint in (253) against tone spreading is only shown at the word level because it does not affect any of the essential candidates at the stem and phrase level.

The constraint CUM-H is only high ranked at the word level. Here, when a prosodic word has more than one H tone, candidates which overwrite a H tone with a L tone will win because CUM-H is ranked above MAXτ—σ and DEP-τ. To avoid CUM-H repairs where a H tone is simply delinked and remains toneless, or where the H tones merge by spreading (and delinking), $\tau \leftarrow \sigma$ and $\underset{*}{\vdash} \leq \overset{o}{o}$ have to be ranked above DEP-τ.

(278) Word-level ranking

*X DEP-o CULM-H $\overset{*o\ o}{\underset{\sigma}{\backslash /}}$ $\overset{*T\ T}{\underset{o}{\backslash /}}$ $\overset{*o}{\underset{\sigma\,\sigma}{/|}}$ $\overset{*T}{\underset{o\ o}{/|}}$ MAX-V MAX-τ $\gg$ $\overset{\tau]_\omega}{\underset{\sigma}{\downarrow}}$ $\gg$ MAX$\overset{\tau}{\underset{\sigma}{|}}$ $\gg$ $\overset{\tau}{\underset{\sigma}{\uparrow}}$ $\gg$ DEP-τ DEP$|$

The phrase-level ranking applies for all data at the post-lexical level. Here, DEP-o is lower ranked compared to the stem and word level. This makes it possible for unstable nouns to link to their lexical tone in the nominative case when there is no other possibility of getting a tonal specification. The constraints $\tau \leftarrow \sigma$ and $\underset{*}{o} \leq \overset{\sigma}{\sigma}$ must dominate DEP-o so that unstable nouns do not remain toneless or get a tone through spreading from adjacent words.

The OCP-L is ranked above DEP-τ to ensure that H tone epenthesis can repair sequences with adjacent L tones. To avoid such repairs creating contour tones, $\overset{o}{\underset{*}{o}} \geq \sigma$ and $\underset{*}{\vdash} \geq o$ must be ranked at the same level as the OCP-L. Furthermore, in sequences with e.g., two adjacent L-toned syllables, H tone epenthesis will overwrite the non-final tone of the p-phrase (e.g., the possessum noun) rather than the final one (e.g., the possessor noun) because MAX$\tau]_\phi$—σ is ranked above MAXτ—σ.

Finally, the constraints *CC$]_\sigma$, $\tau \leftarrow \sigma$, and MAX$_\omega$[V must dominate MAX-V. For unstable nouns with a toneless suffix, this ranking generates outputs where the toneless suffix is deleted instead of (i) only the vowel of the suffix or (ii) the unstable stem itself.

(279) Phrase-level ranking

*CC$]_\sigma$ *X MAX$_\omega$[V OCP-L MAX$\overset{\tau]_\phi}{\underset{\sigma}{|}}$ $\overset{\tau}{\underset{\sigma}{\uparrow}}$ $\overset{*o}{\underset{\sigma\,\sigma}{/|}}$ $\overset{*o\ o}{\underset{\sigma}{\backslash /}}$ $\overset{*T\ T}{\underset{o}{\backslash /}}$ $\gg$ DEP-o $\gg$ MAX$\overset{\tau}{\underset{\sigma}{|}}$ MAX-V $\gg$ $\overset{\tau]_\phi}{\underset{\sigma}{\downarrow}}$ DEP$|$ DEP-τ

As mentioned in section 9.2, floating tones which fail to associate are not deleted across the levels. Furthermore, I assume that autosegmental well-formedness restricts candidates which do not follow the structural hierarchy of syllable to root node association and root node to tone association. This implies that if a syllable lacks a root node, a tone cannot associate directly to the syllable without inserting a root node (or a tonal tree).

9.5 Plural evaluations

The stable stems in the plural are characterized by their surfacing with a high tone on the suffix: -*ṇ̣í*. They start out with with a lexical tone (H, HL, or L) specified in the input.

9.5.1 L-toned stems

Starting with lexical L tones, the stable noun *gwàk* 'fox' goes first through the stem-level evaluation. The input has a L-toned root and the plural H tonal tree ($^{\mathbf{H}}$) (280). In Tableau (282), if the H tonal tree links to the stem, it will violate $\overset{o}{\underset{*}{o}} \dashrightarrow \sigma$ which disfavors a syllable with different association lines (candidate b). By delinking the lexical tone, the plural H tonal tree will not create a contour tone; however, this violates MAXτ—σ which bans deletion of the association line between a tone and its syllable (candidate c). Therefore, the winner is candidate (a) which still has the H tonal tree floating on the right side. To generate this output, the constraints MAXτ—σ and $\overset{o}{\underset{*}{o}} \dashrightarrow \sigma$ must dominate $\tau]_\omega \rightarrow \sigma$. If the ranking were the other way around, candidate (b) or (c) would win instead of candidate (a).

(280) Stem-level input:
/gwàk$^{\mathbf{H}}$/ 'fox'

(281) Stem-level output:
gwàk$^{\mathbf{H}}$

(282) *Stem level:* plural stable noun

L H / o o / σ	MAX $\tau \| \sigma$	DEP-o	*o o $\backslash /$ σ	MAX-V	DEP-τ	MAX T | o	$\tau \uparrow \sigma$	$\tau]_\omega \downarrow \sigma$	DEP|
a. ☞ L H / o o / σ								⋆	
b. L H / o o / σ			⋆!						⋆
c. L H / o o / σ	⋆!								⋆

The winner of the stem level serves as an input at the word level. This includes the H tonal tree which could not link to a syllable, and the toneless suffix -*ṇ̣i* which appears at this level (283).

In Tableau (285), the H tonal tree has to link to the toneless suffix to avoid violating $\tau \leftarrow \sigma$. However, candidates are, however, ruled out by other higher-ranked constraints. If the H tone links to the stem syllable by deleting the association between the stem and its lexical tone as in candidate (b), this violates MAXτ—σ. By not delinking the lexical tone (candidate e), $\overset{\text{o}}{\underset{*}{\text{o}}} \succ \sigma$ is violated. Deleting the whole suffix (candidate d) prevents violations of $\tau \leftarrow \sigma$. However, this fatally violates MAX-V. Candidate (c) is the same as the input violating $\tau]_{\omega}\!\rightarrow \sigma$ because the H tonal tree is the last tone in the prosodic word. The winner is candidate (a) where the H tonal tree from the stem level has linked to the suffix. This results in a H-toned suffix in the nominative plural (284). The dominance of $\tau]_{\omega}\!\rightarrow \sigma$ and $\tau \leftarrow \sigma$ above DEP| ensures that the right-most tone (plural H tonal tree) links to the toneless syllable. The opposite ranking would lead to the winner being candidate (c). The winner also relies on the survival of the floating H tonal tree from the stem level because it does not link to a syllable until this word level. It is also important that MAX-V is ranked high. If it were ranked below DEP|, then candidate (d) would win which deleted the suffix.

(283) Word-level input:
/gwàk$^{\mathbf{H}}$ -ni̤/ 'fox'

(284) Word-level output:
gwàk-ní̤ 'foxes'

(285) *Word level:* plural stable noun

L H / | | / o o / | / σ -σ	*X	DEP-o	CULM-H	*o o \/ σ	*T T \/ o	*o /| σ σ	MAX-V	$\tau]_{\omega}$ ↓ σ	MAX τ | σ	τ ↑ σ	DEP-τ	DEP|
a. ☞ L H / | | / o o / | ¦ / σ -σ												*
b. L H / | | / o o / ǂ / / σ -σ									*!	*		*
c. L H / | | / o o / | / σ -σ								*!		*		
d. L H / | | / o o / | / σ							*!	*				
e. L H / | | / o o / | / / σ -σ				*!						*		*

At the phrase level, the input for stable stems has the H-toned -*ní̤* from the word level. In addition, the L tonal tree appears when nouns are inflected for the oblique case (286). In Tableau (288), any attempt of linking the L tonal tree to the suffix is penalized. Candidates (d–e) have different ways of deleting the H tone linked to -*ní̤* by delinking the lower or the upper part of the association line. Because this tone is linked to a p-phrase-final syllable, the deletions fatally violate MAX $\tau]_\phi$–σ, but more importantly, candidates (d–e) also violate OCP-L because the stem tone is also L-toned. Candidates (b–c) link the L tonal tree without deleting the association line to the suffix. This creates a root node or syllable with different association lines violating $\underset{*}{\text{T}} \dashrightarrow$ o and $\underset{*}{\text{o}} \dashrightarrow \sigma$, respectively. The winner is candidate (a) which lets the L tonal tree float. The output is the same as in the nominative plural (287). The crucial ranking is that MAX $\tau]_\phi$–σ together with $\underset{*}{\text{o}} \dashrightarrow \sigma$ and $\underset{*}{\text{T}} \dashrightarrow$ o, dominate $\tau]_\phi \rightarrow \sigma$ since it is more important for tones which are linked to a syllable in the input to remain linked in the output than to associate the tonal tree. Note that the L tonal tree does not induce downstep – see section 9.2.

(286) Phrase-level input: /gwàk-ní̤ $^{\text{L}}$/ 'foxes'

(287) Phrase-level output: gwàk-ní̤ 'foxes'

(288) *Phrase level:* plural oblique case with stable noun

L H L / o o o / (...) σ -σ	MAX$_\omega$[V	OCP-L	MAX $\tau]_\phi$ | σ	τ ↑ σ	*o /| σ σ	*o o \\/ σ	*T T \\/ o	DEP-O	MAX τ | σ	MAX-V	$\tau]_\phi$ ↓ σ	DEP|	DEP-τ
a. ☞ L H L / o o o / (...) σ -σ											*		
b. L H L / o o o / (...) σ -σ							*!					*	
c. L H L / o o o / (...) σ -σ						*!						*	
d. L H L / o o o / (...) σ -σ		*!	*						*			*	
e. L H L / o o o / (...) σ -σ		*!	*						*			*	

The plural oblique inflection of the hybrid stems is shown in Tableau (291). The input has two floating tones: a lexical L tone and the HL tonal tree marking the plural (289) since this noun is specified for this plural tonal allomorph. Candidate (d) is the same as the input violating $\tau \leftarrow \sigma$, because the stem is not linked to a tone, as well as $\tau]_{\omega} \rightarrow \sigma$ because the right-most tone of the prosodic word remains floating. If only the lexical tone links to the stem (candidate c), it prevents a violation of $\tau \leftarrow \sigma$ but still fatally violates $\tau]_{\omega} \rightarrow \sigma$. Candidate (e) shows an interesting option of the autosegmental structures where both tonal trees are linked to the stem, but the association line between the L tone and the root node is deleted. This violates MAX T—o because of the deletion of the association line between the tone and the root node. Candidate (b) has both tones linked to the stem. This does not violate $\overset{o}{\underset{*}{o}} \leftleftarrows \sigma$ because the syllables have the same type of association lines (both inserted), but candidate (a) is the winner where only the right-most floating tone, the HL tonal tree, has linked to the stem. Thus, the fact that DEP| is gradient determines that candidate (a) wins over candidate (b) because the former has only one inserted association line while the latter has two. The output is shown in (290).

(289) Stem-level input:
/^{L}rɔaːm^{HL}/ 'sheep' (SG)

(290) Stem-level output:
^{L}rɔ̂ːm 'sheep' (PL)

(291) *Stem level,* PL. Input: hybrid singular noun + HL tonal tree (allomorph of PL)

L HL / o o / σ_{HL}	MAX τ|σ	DEP-o	*o o \/ σ	MAX-V	DEP-τ	MAX T|o	$\tau \uparrow \sigma$	$\tau]_{\omega} \downarrow \sigma$	DEP|
a. ☞									⋆
b.									⋆⋆!
c.								⋆!	⋆
d.							⋆!	⋆	
e.						⋆!			⋆⋆

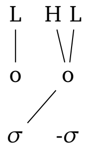
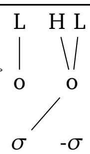
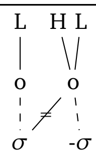
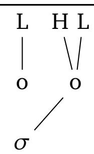
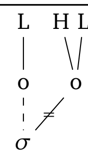
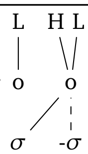
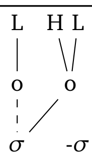
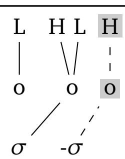
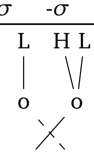
At the word level, the winning candidate from the stem level is the input with a HL tone linked to the stem and the floating L tonal tree. The toneless suffix -*ni̤* is added to the input of plural stems (292). It is essential that DEP-o,$\underset{*}{\mathrm{o}} \leq \overset{\sigma}{\sigma}$, *X, and MAX-V are ranked above $\tau \leftarrow \sigma$. The outcome of this ranking is that the suffix cannot get a tone by any of the following processes: (i) tone spreading from the stem tone because it violates $\underset{*}{\mathrm{o}} \leq \overset{\sigma}{\sigma}$ (candidate e); (ii) it also cannot link the floating lexical stem tone on the left side because the association lines will cross (candidate h); and (iii) it is impossible to insert a root node and a tone which then link to the suffix because it violates DEP-o and DEP-τ (candidate g). Inserting a tonal tree would involve the same violations. The latter candidate also violates CULM-H because the epenthesized H tone creates two H tones in a prosodic word. When the whole toneless suffix is deleted, this violates MAX-V since the vowel is deleted (candidates c–d). The lexical tone cannot link to the stem because this would create a syllable with different association lines, fatally violating $\overset{\mathrm{o}}{\underset{*}{\mathrm{o}}} \gtrsim \sigma$ (candidate f). Delinking and shifting the tone from the stem to the suffix violates MAX τ—σ (candidate b).

The winner is candidate (a) where the suffix remains toneless in the output. This only violates the lower ranked $\tau \leftarrow \sigma$. Thus, the output of the word level has a toneless suffix and the floating tonal tree (293), which is shipped to the phrase level.

(292) Word-level input:
/ᴸrɔ̂ːm-ni̤/ 'sheep' (PL)

(293) Word-level output:
ᴸrɔ̂ːm-ni̤

(294) *Word level:* plural hybrid noun with HL tonal tree (tonal allomorph of PL)

	*X	DEP-o	CULM-H	*o o \ / σ	*T T \ / o	*o / | σ σ	MAX-V	$\tau]_\omega$ ↓ σ	MAX τ | σ	τ ↑ σ	DEP-τ	DEP|
a. ☞ 										*		
b. 									*!			**
c. 							*!					
d. 							*!	*	*			*
e. 						*!						*
f. 				*!						*		*
g. 		*!	*								*	**
h. 	*!											*

At the phrase level, the noun can get inflected for the oblique case, or it can remain as nominative plural. The latter is shown first in Tableau (297) below. The candidates are represented with segmental material to illustrate how the whole suffix gets deleted (as opposed to not deleting it, or deleting only the vowel). The input is $^{\mathrm{L}}$*rɔ̂ːm-ṇ̈i* with a toneless suffix (295). There are no exponents at this stratum for the nominative case since the noun already has the plural exponents from the stem and word level. This means that the input has a toneless suffix which violates the high-ranked constraint $\tau \leftarrow \sigma$ (candidate f). The only floating tone which can link to the suffix is the lexical L tonal tree positioned at the left side of the stem. When this links to the suffix, *X is fatally violated since this involves crossing of association lines (candidate i).

As has already been shown, tone spreading violates $\underset{*}{\circ} \preceq \overset{\sigma}{\sigma}$ in Nuer so syllables cannot get a tone this way as in candidate (e). When the stem tone is delinked before it links to *-ṇ̈i*, this avoids violating $\underset{*}{\circ} \preceq \overset{\sigma}{\sigma}$, but it fatally violates MAX $\tau]_{\phi}$–σ and MAX τ—σ (candidates g and h). Tone insertion must involve an inserted root node in order for it to link to the suffix, and this fatally violates DEP-o (candidate b). The solution is to delete the suffix. When only the vowel is deleted as in candidate (j), this creates a complex coda (**rɔ̂ːmn*) fatally violating *CC$]_{\sigma}$. The winner is (a) which has deleted the entire suffix. The lexical tonal tree to the left of the stem remains floating. Candidates which link this tone to the stem lose because they violate the constraints $\underset{*}{\overset{\circ}{\circ}} \succeq \sigma$ and $\underset{*}{\overset{\vdash}{\vdash}} \succeq \circ$ (candidates c–d). Since this L is a tonal tree, it does not have a phonetic effect in the output (296) – see section 9.2.

(295) Phrase-level input (nominative):
/$^{\mathrm{L}}$rɔ̂ːm-ṇ̈i/ 'sheep' (PL)

(296) Phrase-level output (nominative):
rɔ̂ːm 'sheep' (PL)

(297) *Phrase level:* plural nominative case with hybrid noun

L H L o o rɔːm -ni̤	$*CC]_\sigma$	*X	$MAX_\omega\lceil V$	OCP-L	MAX $\tau]_\phi$ | σ	$\tau \uparrow \sigma$	*o / $\sigma\,\sigma$	*o o \ / σ	*T T \ / o	DEP-o	MAX τ | σ	MAX-V	$\tau]_\phi \downarrow \sigma$	DEP|	DEP-τ
a. ☞ L H L o o rɔːm												*			
b. L H L L o o o rɔːm -ni̤										*!				**	*
c. L H L o o rɔːm									*!			*		*	
d. L H L o o rɔːm								*!				*		*	
e. L H L o o rɔːm -ni̤							*!							*	
f. L H L o o rɔːm -ni̤						*!									
g. L H L o o rɔːm -ni̤					*!	*					*			*	
h. L H L o o rɔːm -ni̤					*!						*			**	
i. L H L o o rɔːm -ni̤		*!												*	
j. L H L o o rɔːm -n	*!											*			

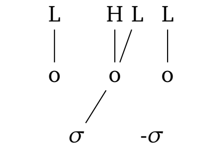
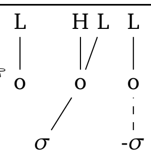
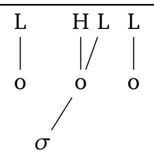
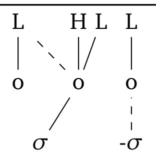
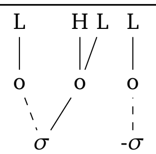
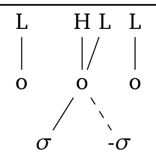
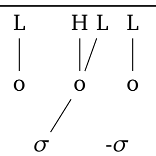
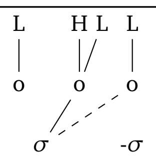
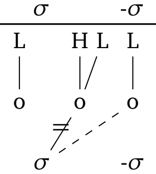
Tableau (300) shows the inflection of the oblique case in the plural. The input is the winner of the word level of Tableau (294) with the addition of the L tonal tree marking the oblique case. This means that there is a floating tone right-most in the p-phrase which can freely link to the toneless suffix. The input (f) and the candidates (g–h) fatally violate $\tau \leftarrow \sigma$ and other constraints since the suffix remains toneless. Candidate (e) is also excluded because it spreads the stem tone onto the suffix violating $\underset{*}{\circ} \leq \overset{\sigma}{\sigma}$. The HL tone is the only tone linked to a syllable in the input and, it therefore belongs to the right-most syllable of the p-phrase. Deleting its association line violates MAX $\tau]_{\phi}$–σ (candidate h). The lexical L tone to the left of the stem cannot link to any syllable without fatally violating the constraints against different association lines (candidates c–d).

The winner is candidate (a) where the L tonal tree is linked to the suffix. This output is shown in (299). The constraint DEP| must be ranked below MAX-V to prevent candidate (b), which has deleted the suffix, from winning instead of (a). As was mentioned for the winner of Tableau (297) above, the L tonal tree, which floats on the left side, does not induce downstep.

(298) Phrase-level input (oblique case):
/$^{\mathbf{L}}$rɔ̂ːm-ni̤$^{\mathbf{L}}$/ 'sheep' (PL)

(299) Phrase-level output (oblique case):
rɔ̂ːm-nì̤ 'sheep' (PL\OBL)

(300) *Phrase level:* plural oblique case with hybrid noun

	MAX$_\omega$[V	OCP-L	MAX $\tau]_\phi$ | σ	τ ↑ σ	*o /| $\sigma\sigma$	*o o \/ σ	*T T \/ o	DEP-o	MAX τ | σ	MAX-V	$\tau]_\phi$ ↓ σ	DEP|	DEP-τ
a. ☞ 												*	
b. 										*!	*		
c. 							*!					**	
d. 						*!						**	
e. 					*!						*	*	
f. 				*!							*		
g. 				*!		*						*	
h. 			*!	*					*			*	

The crucial difference between the stable and hybrid stems is that the former has no linked lexical tone in the input. This difference determines whether the plural H or HL tonal trees will link to the stem or to the toneless suffix at the word level. If it can link to *ṇ̤i̤* early, as with stable stems, it will be too late for the L tone of the oblique case to link to it at the phrase level. Therefore, stable stems have a H-toned *-ṇ̤i̤* also in the oblique case plural. If the plural H tonal tree instead goes on the stem, as for hybrid and unstable stems, *n̤i̤* remains toneless until the phrase level where it can get the L tone in the oblique case. In this sense, a disyllabic or a monosyllabic structure relies crucially on the nature of the stem tone in the input as well as the stratal evaluation where the plural exponents belong to different levels.

9.5.2 H-toned stems

The tableaux presented in the previous section evaluated plurals from L-toned singular stems. When stable nouns have a L tone, they do not alter this lexical stem tone because it is linked in the input. When the stem tone is H or HL, the stem tone changes to a L tone as was shown in section 7.3.2. This change of stem tone is triggered by the H tone of the suffix. That is, when the L-toned oblique singular suffix *-kɛ̤̀* is added, the stems mostly stay the same. For example in (301), the H-toned noun *gá̤ˑc* stays H before the singular *-kɛ̤̀* (301b), but it gets a L tone before *n̤í̤* in (301c). The same can be observed for the HL-toned noun in (302).

(301) ‘belt’
  a. gá̤ˑc NOM.SG
  b. gá̤ˑj-kɛ̤̀ OBL.SG
  c. gà̤ˑc-n̤í̤ NOM.PL/OBL.PL

(302) ‘soldier’
  a. dêˑc NOM.SG
  b. dêc-kɛ̤̀ OBL.SG
  c. dèˑj-n̤í̤ NOM.PL/OBL.PL

The irregular stable noun *bṳ́ˑk*, which fails to get *-kɛ̤* in the oblique singular form also changes to a L tone before *-n̤í̤* in (303b).

(303) ‘Nuer god’
  a. bṳ́ˑk NOM.SG
  b. bṳ̀ɔ̤ːŋ-í̤ NOM.PL/OBL.PL

The H and HL-tone simplification on the stems happens at the word level when the H-toned *n̤í̤* is added in the plural nominative. Inputs with two H tones violate the constraint culminativity of H tones in a prosodic word. Tableaux for these processes are shown below.

Tableau (306) shows the stem level inflection of the H-toned root *gá̤·c* which has a plural H tonal tree floating in the input (304). Just as in Tableau (282), this H tonal tree remains floating because linking it to the stem fatally violates MAX τ—σ (candidate c) or $\overset{o}{\underset{*}{o}} \dashrightarrow \sigma$ (candidate b). The winner is the input: candidate (a) with the output in (305).

(304) Stem-level input:
gá̤·c^H ‘belt’

(305) Stem-level output:
gá̤·c^H

(306) *Stem level*: plural stable H-toned noun

H H / o o / σ (H–o–σ; H–o)	MAX τ | σ	DEP-o	*o o \/ σ	MAX-V	DEP-τ	MAX T | o	$\tau \uparrow \sigma$	$\tau]_\omega \downarrow \sigma$	DEP|
a. ☞ H H / o o / σ								⋆	
b. H H / o o / σ (both o linked to σ)			⋆!						⋆
c. H H / o o / σ (first o delinked, second o linked)	⋆!								⋆

The winner of the stem level is the input at the word level. This includes the H tonal tree, which could not link to a syllable, and the toneless suffix *-ṇ̤i̤*, which appears in the input at this level (307). The Tableau below in (309) shows the evaluations. Just as was observed in Tableau (285) with L-toned stems, the H tonal tree is right-most in the prosodic word and must link to a syllable to avoid violating $\tau]_{\omega}\!\rightarrow\sigma$ (candidates c–e). When the H tone links to the suffix, CULM-H is fatally violated because there are two H tones in a prosodic word. Thus, candidate (j) is out because the noun has two H tones. Even if a L tone links to one of the syllables, as in candidates (i, k), CULM-H is still violated because the H tones have not been delinked. That is, HL-H and H-HL count as violations of CULM-H. The ways to repair this is to delete one of the H tones. Candidate (c) deletes the H association line between the plural H tone and its root node giving a H-L sequence. This solution fatally violates $\tau]_{\omega}\!\rightarrow\sigma$ because the plural H tonal tree is now floating. Other candidates which repair CULM-H by merging the H tones violate the constraints against tone spreading, e.g. candidate (g) spreads the H tone from the root node violating $\underset{*}{\circ} \leq \genfrac{}{}{0pt}{}{\sigma}{\sigma}$, while candidate (f) violates $\underset{*}{\vdash} \leq \genfrac{}{}{0pt}{}{\circ}{\circ}$ by spreading the tone onto the root node of the stem.

It is a close call between candidates (a–b). Candidate (b) links the plural H tonal tree to the stem and delinks the stem tone. This candidate loses because the toneless suffix violates $\tau \leftarrow \sigma$. Candidate (a) is the winner which overwrites the H stem tone with a L. This only violates the lower-ranked constraint MAXτ—σ. The output is the L-H sequence in (308), with the delinked lexical H tone.

(307) Word-level input:
/gá̤·c**H**-ni̤/ 'belts'

(308) Word-level output:
Hgà̤·c-ní̤

(309) *Word level:* plural stable H-toned noun

H H o o σ -σ	*X	DEP-o	CULM-H	*o o / σ	*T T / o	*o / σ σ	*T / o o	MAX-V	τ]$_\omega$ ↓ σ	MAX τ | σ	τ ↑ σ	DEP-τ	DEP|
☞a. H L H o o σ -σ										⋆		⋆	⋆⋆
b. H H o o σ -σ										⋆	⋆!		⋆
c. H L H o o σ -σ									⋆!			⋆	⋆⋆
d. H H o o σ -σ									⋆!		⋆		
e. H H o o σ								⋆!	⋆				
f. H H o o σ -σ							⋆!			⋆			⋆⋆
g. H H o o σ -σ						⋆!				⋆			⋆⋆
h. H H o o σ -σ				⋆!							⋆		⋆
i. H L H o o σ -σ			⋆!		⋆							⋆	⋆⋆
j. H H o o σ -σ			⋆!										⋆
k. H L H o o σ -σ			⋆!		⋆							⋆	⋆⋆

At the phrase level, the input for stable stems has the H-toned *-ṇ̈í* from the word level together with the L tonal tree marking the oblique case. The evaluation below in Tableau (312) is similar to the one for stable L tones in Tableau (288) in section 9.5.1. The difference is that there is a floating H tone before the stem. This is the lexical tone which was delinked at the word level in the previous tableau. If the L tonal tree links to the suffix, this leads to violations of the constraints $\overset{\mathrm{o}}{\underset{*}{\mathrm{o}}} \dashrightarrow \sigma$ (candidate e) and $\underset{*}{\vdash\!\vdash} \dashrightarrow \mathrm{o}$ (candidate c). Delinking the H tone of the suffix violates the OCP-L because this creates syllables with adjacent L tones (candidates f–g). When the floating H tone links to the stem, this violates $\underset{*}{\vdash\!\vdash} \dashrightarrow \mathrm{o}$ (candidate d). When the stem tone is delinked, a violation of the latter constraint is avoided, but this violates the constraint MAXτ—σ , excluding candidate (b). The winner is candidate (a) where the tones remain floating. These tones do not have a phonetic effect on the linked tones and the output is L-H. First, floating H tones do not affect the register of other tones because Nuer has no upstep, and second, the L tonal tree cannot create a downstep. Thus, these tones are simply not pronounced in the output (311).

(310) Phrase-level input:
/^{H}gạ̀̈ˑc-nị̈́^{L}/ 'belts'

(311) Phrase-level output:
gạ̀̈ˑc-nị̈́

(312) *Phrase level:* plural oblique case with stable H-toned noun

H L H L o o o (…) σ -σ	MAX$_\omega$[V	OCP-L	MAX $\tau]_\phi$ / σ	τ ↑ σ	*o / $\sigma\,\sigma$	*o o / σ	*T T / o	DEP-o	MAX τ / σ	MAX-V	$\tau]_\phi$ ↓ σ	DEP|	DEP-τ
a. ☞ H L H L o o o (…) σ -σ											⋆		
b. H L H L o o o (…) σ -σ									⋆!		⋆	⋆	
c. H L H L o o o (…) σ -σ							⋆!					⋆	
d. H L H L o o o (…) σ -σ							⋆!				⋆	⋆	
e. H L H L o o o (…) σ -σ						⋆!						⋆	
f. H L H L o o o (…) σ -σ		⋆!	⋆						⋆			⋆	
g. H L H L o o o (…) σ -σ		⋆!	⋆						⋆!			⋆	

9.6 Singular evaluations

The singular nouns go through the exact same levels as the plurals and have the same rankings. The difference is that there are no plural exponents: no H/HL tonal trees at the stem level and no suffix at the word level. Thus, there is no added phonological material for these derivations. For the stable and unstable stems, the evaluations at the stem and word level are vacuous since there is no change from input to output. No phonological operations applies because of the constraint rankings. Regarding stable stems, the lexical tone is already linked to the stem, and there are no grammatical tones at the stem level. Therefore, nothing can be improved with the rankings in the Nuer grammar. Concerning the unstable stems, the evaluations are also vacuous because the stem lacks a root node. At the stem and word levels, insertion of a root node would make tone-syllable linking possible. However, this is more expensive than having toneless syllables because DEP-o is higher ranked than $\tau \leftarrow \sigma$. Therefore, at the stem and word level, the lexical tone remains floating in singular unstable nouns.

Unstable stems do not get a tone until the phrase level. Here, when they are inflected for the oblique case, they get a tone from the L tonal tree which marks this case. If they remain as singular nominative nouns, root node insertion will happen to prevent toneless syllables of nouns in the output. This makes it possible for the lexical tones to link to the stems.

The hybrid nouns are the only ones with a non-vacuous evaluation since they link the tonal tree to the stem at the stem-level. In this section, the hybrid stem is evaluated first followed by stable and unstable stems.

For the hybrid stem, the evaluation is not vacuous at the stem level because they have a floating lexical tonal tree. An example is the noun *rɔ̀a:m* 'sheep' SG in (313). Tableau (315) shows the evaluation of lexical tone associations of this type of noun. Candidate (b) is the same as the input which violates $\tau \leftarrow \sigma$, because the stem is not linked to a tone, as well as $\tau]_{\omega} \rightarrow \sigma$ because the lexical tonal tree, which is floating, is right-most in the prosodic word. Candidate (c) is out because it has has deleted the L tonal tree violating MAX-τ against tone or tonal tree deletion. The same goes for candidate (d) which has deleted the association line between the root node and the tone violating the constraint MAX T—o. Note that it does not violate MAX τ—σ because the tone is not linked to the syllable in the input. Deleting the whole stem violates MAX-V since it involves deleting the vowel – eliminating candidate (e). The winner is candidate (a) where the lexical tone has linked to the stem. The output is the L-toned noun in (314).

(313) Stem-level input:
/ᴸrɔa:m/ 'sheep' (SG)

(314) Stem-level output:
rɔ̀a:m

(315) Stem level, singular. Input: hybrid L-toned noun

$\begin{matrix}L\\ \vert\\ o\\ \\ \sigma\end{matrix}$	MAX $\begin{matrix}\tau\\ \vert\\ \sigma\end{matrix}$	DEP-o	$\begin{matrix}{*}o\ o\\ \backslash\ /\\ \sigma\end{matrix}$	MAX-V	DEP-τ	MAX $\begin{matrix}T\\ \vert\\ o\end{matrix}$	MAX-τ	$\begin{matrix}\tau\\ \uparrow\\ \sigma\end{matrix}$	$\begin{matrix}\tau]_{\omega}\\ \downarrow\\ \sigma\end{matrix}$	DEP|
a. ☞ $\begin{matrix}L\\ \vert\\ o\\ \vdots\\ \sigma\end{matrix}$										⋆
b. $\begin{matrix}L\\ \vert\\ o\\ \\ \sigma\end{matrix}$								⋆!	⋆	
c. σ							⋆!			
d. $\begin{matrix}L\\ \nmid\\ o\\ \\ \sigma\end{matrix}$						⋆!		⋆	⋆	
e. $\begin{matrix}L\\ \vert\\ o\end{matrix}$				⋆!					⋆	

At the word level, the evaluation is vacuous for the hybrid stem. This is shown below in Tableau (318). The input is the winner from the stem level where the lexical tone has linked to the stem. There are no other exponents because this is the singular nominative. Deletion of the tone-syllable association from the input violates MAXτ—σ (candidate b). It also violates $\tau]_{\omega}\!\rightarrow\sigma$, because the lexical tone is floating and positioned final in the prosodic word, and $\tau\leftarrow\sigma$, because the stem remains without a tone. Therefore, the winner is candidate (a) which is the same as the input.

(316) Word-level input:
/rɔ̀aːm/ 'sheep' (SG)

(317) Word-level output:
rɔ̀aːm (vacuous)

(318) *Word level:* singular hybrid noun

L | o | σ	*X	DEP-o	CULM-H	*o o \/ σ	*T T \/ o	*o /| $\sigma\,\sigma$	MAX-V	MAX-τ	$\tau]_{\omega}$ ↓ σ	MAX τ | σ	τ ↑ σ	DEP-τ	DEP|
a. ☞ L | o | σ													
b. L | o ǂ σ									*!	*	*		

At the phrase level, the L tonal tree and the toneless suffix *-kɐ̤* appear as oblique exponents. The input is shown in (319). Candidate (e) is the same as the input. This violates $\tau \leftarrow \sigma$ and $\tau]_{\phi} \rightarrow \sigma$ because the suffix is toneless and the L tonal tree is floating. Candidate (f) is also out because it violates $\tau \leftarrow \sigma$. The L tonal tree cannot link to the stem because it already has a tone in the input. This creates different association lines ruling out candidate (c), and creating an additional violation in (f), because they violate $*\tau\tau \rightrightarrows o$ and $*oo \rightrightarrows \sigma$, respectively. Avoiding such violations can be done by deleting the stem tone. However, this is fatally penalized by MAX $\tau]_{\phi}-\sigma$ in candidate (g) because the stem tone is the right-most linked tone of its p-phrase.

If the L tonal tree links to the suffix, this will violate OCP-L because it leads to two adjacent L tones. Candidate (h) is therefore out. Deleting the syllable vowel fatally violates MAX-V and also $\tau]_{\phi} \rightarrow \sigma$ (candidate b). The winner is candidate (a) where a H tone has been inserted and linked to the suffix. The H tone takes the root node of the oblique marker by associating to it. The association between the L tone and the root node is deleted. This does not lead to any faithfulness violations because the L tone was never linked to the syllable in the input.

It is crucial here that the OCP-L is ranked above DEP-τ. With the opposite ranking, candidate (h) would win out over candidate (a). The output is a L-toned stem with a H-toned suffix (320).

(319) Phrase-level input:
/rɔ̀aːm-kɐ̤^{L}/ sheep-OBL.SG

(320) Phrase-level output:
rɔ̀ːm-kɐ̤́ sheep-OBL.SG

(321) *Phrase level:* singular oblique case with hybrid noun

L L / o o / σ -σ	$MAX_{\omega}[V$	OCP-L	MAX $\tau]_{\phi}$ | σ	$\tau \uparrow \sigma$	*o / | $\sigma\ \sigma$	*o o \ / σ	*T T \ / o	DEP-o	MAX τ | σ	MAX-V	$\tau]_{\phi} \downarrow \sigma$	DEP|	DEP-τ
a. ☞												⋆⋆	⋆
b.										⋆!	⋆		
c.							⋆!					⋆⋆	⋆
d.					⋆!						⋆	⋆	
e.				⋆!							⋆		
f.				⋆!		⋆						⋆	
g.			⋆!	⋆					⋆			⋆	
h.		⋆!										⋆	

The next evaluation shows the stable stem. The root contains a linked lexical tone (322). Recall that both the stem and word level are vacuous evaluations because there are no exponents for the singular nouns at these levels. The same goes for the phrase level in the nominative singular derivations.

(322) Stable root with lexical specified L tone: gwàk 'fox'

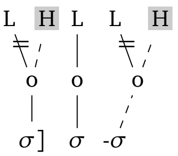
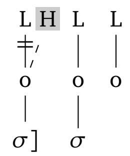
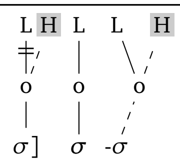
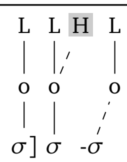
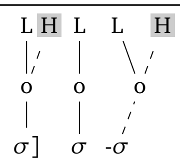
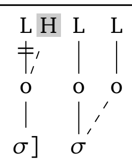
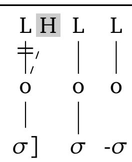
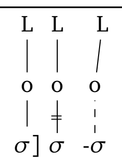
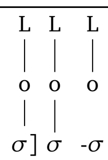
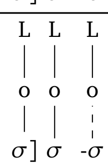
L
|
o
|
σ

Tableau (325) shows the phrase-level evaluation for the L-toned stable noun in the oblique case. The input is given in (323). It has the L-toned stem, the toneless *-kɐ̤*, and the L tonal tree. The noun is adjacent to the L-toned possessum word *cɔ̤̀aː* 'bone' (represented by the right bracket in the tableau). The input, candidate (i), violates OCP-L because the possessor stem and the possessum noun are L-toned. If the L tonal tree links to the suffix, this induces two OCP-L violations (candidate j). These two candidates are therefore ruled out. Candidate (h) deletes the L tone in the middle of the L L-L sequence. According to the definition in (237), this does not violate the OCP-L because the L-toned syllables are no longer adjacent since there is a toneless syllable between them. However, this candidate is ruled out because it violates MAX $\tau]_{\phi}$–σ by deleting an association line between a tone and a syllable which are right-most in the p-phrase. The solution is to insert a H tone to avoid adjacent L tones (candidates a–g). The most efficient way to repair an OCP-L violation and still link the L tonal tree is to insert a H tone in the middle; i.e., to the stem of the possessor noun to avoid deleting the L tone of the stem. This is done in candidate (d), which avoids violating the constraint MAX $\tau]_{\phi}$–σ but fatally violates *TT ⇉ o. By deleting the toneless suffix, H tone epenthesis only needs to target one syllable. However, this violates MAX-V and is ruled out (candidate b). The winner is candidate (a) where the OCP-L repair involves inserting H tones at the right and left of the L-toned syllables. This is accompanied by deletion of the association lines of the syllable tone in the possessum noun and of the root node–tone association line of the L tonal tree. This prevents contour tones with different association lines. The output is shown in (324). The delinked L tone to the left induces downstep on the H tone of ꜜ*cɔ̤́aː*.

(323) Phrase-level input:
cɔ̤̀aː gwàk-ɐ̤^{L}
bone fox-OBL.SG

(324) Phrase-level output:
ꜜcɔ̤́aː gwàk-ɐ̤́
bone fox-OBL.SG

(325) *Phrase level:* singular oblique case with stable noun

Input=(i)	MAX$_\omega$[V	OCP-L	$\tau]_\phi$ MAX σ	$\tau \uparrow \sigma$	*o /| $\sigma\,\sigma$	*o o \ / σ	*T T \ / o	DEP-o	MAX τ | σ	MAX-V	$\tau]_\phi \downarrow \sigma$	DEP|	DEP-τ
a. ☞ 									⋆			⋆⋆⋆	⋆⋆
b. 									⋆	⋆!	⋆	⋆	⋆
c. 							⋆!		⋆			⋆⋆⋆	⋆⋆
d. 							⋆!					⋆⋆	⋆
e. 							⋆!					⋆⋆⋆	⋆⋆
f. 						⋆!			⋆	⋆		⋆⋆	⋆
g. 				⋆!					⋆		⋆	⋆	⋆
h. 			⋆!	⋆					⋆			⋆	
i. 		⋆!		⋆							⋆		
j. 		⋆!⋆										⋆	

Finally, the unstable nouns are evaluated in the singular. Recall that unstable stems have a floating lexical tone but lack a root node. Therefore, the evaluations at the stem and word level are vacuous because a root node or a tonal tree can never be inserted because of the ranking of DEP-o. Thus, the lexical tone does not get a chance to link to the stem until the phrase level.

Tableau (328) shows the stem-level evaluation. Candidate (e) inserts a root node so that the lexical tone can link to the stem. This fatally violates DEP-o. Candidate (c) has deleted the vowel of the syllable. This is ruled out by the high ranking of MAX-V since it involves vowel deletion. Candidate (b) has deleted the tone. This prevents violations of $\tau]_\omega\!\rightarrow\sigma$, however it violates the higher-ranked constraint MAX-τ and is out. The winner is the faithful candidate (a) which remains toneless. The output is shown in (327). The same outcome can be observed at the word level in Tableau (331) below.

(326) Stem-level input:
/$^{\mathrm{L}}$waŋ/ 'eye'

(327) Stem-level output:
$^{\mathrm{L}}$waŋ

(328) *Stem level*: singular unstable L-toned stem

L σ	MAX τ | σ	DEP-o	*o o \\/ σ	MAX-V	DEP-τ	MAX T | o	MAX-τ	$\tau \uparrow \sigma$	$\tau]_\omega \downarrow \sigma$	DEP|
a. ☞ L σ								⋆	⋆	
b. σ							⋆!	⋆		
c. L				⋆!					⋆	
d. L o σ		⋆!						⋆	⋆	
e. L ¦ o ¦ σ		⋆!								⋆⋆

(329) Word-level input:
/^{L}waŋ/ ‘eye’

(330) Word-level output:
^{L}waŋ

(331) *Word level:* singular with unstable noun

L σ	*X	DEP-o	CULM-H	*o o \ / σ	*T T \ / o	*o /| σ σ	MAX-V	MAX-τ	$\tau]_{\omega}$ ↓ σ	MAX τ | σ	τ ↑ σ	DEP-τ	DEP|
a. ☞ L σ									⋆		⋆		
b. σ								⋆!			⋆		
c. L							⋆!		⋆				
d. L ¦ o ¦ σ		⋆!											⋆⋆
e. L o σ		⋆!							⋆		⋆		

Tableau (334) gives the phrase level evaluation of the oblique case inflection of /ᴸwaŋ/ 'eye'. The input has this noun with its lexical floating L tone and the oblique case exponents: a L tonal tree and the toneless suffix -*kɐ̤*. This input is evaluated in the possessive construction with the L-toned possessum noun *c̤ɔ̤̀a̤ː* (332). Thus, there are two toneless syllables with a floating L tone and a L tonal tree in the input which are adjacent to *c̤ɔ̤̀a̤ː* (represented by a square bracket).

If no tones link to the two toneless syllables, as in candidate (e), then $\tau \leftarrow \sigma$ is violated twice. If the L tonal tree links to the suffix, as in candidate (d) and (f), then $\tau \leftarrow \sigma$ is still fatally violated. Note that candidate (d) does not violate the OCP-L because there is a toneless syllable between the two L-toned syllables. Because of the ranking at this level, it is not possible to get surface tones to both the suffix and the stem because there is only one root node. Inserting a tone and a root node violates DEP-O (candidate b). The same violation would occur if a tonal tree were inserted. The unstable stem tone could get a tone through tone spreading from the possessum noun. If so, the OCP-L is not violated as long as a H tone is inserted on the suffix (candidate c). However, this violates $\underset{*}{\circ} \lessdot {}^{\sigma}_{\sigma}$ and is ruled out. The remaining solutions is to delete one of the syllables. When the stem-vowel is deleted and only the suffix is kept, this violates MAX$_{\omega}$[V (candidate k). This constraint demands faithfulness of the left-most vowel in the prosodic word, which is in the stem.

The remaining candidates delete the suffix. The winner is determined by which tone the stem gets. If the L tonal tree links to it, this violates the OCP-L (candidate j). The solution is again to insert a H tone. Now, an essential difference between the unstable stems and the hybrid and stable stems becomes apparent; the stem is not linked to a tone so inserting a H tone here is preferred over inserting it on the possessum noun. Thus, when the candidates (g–i) insert a H tone on the possessum, which fatally violates the MAX $\tau]_{\phi}$–σ constraint. This type of violation occurs because the tone of the possessum noun is the only linked tone of the p-phrase making it the right-most linked tone which should not be deleted. In other words, it is worse to delete the tone of the possessum noun when it is adjacent to an unstable stem compared to when it is adjacent to stable and hybrid stems which have a tone at the phrase level. The winner is candidate (a) where the suffix is deleted, and the H tone links to the syllable of the stem by borrowing the root node of the oblique marker. The association line is deleted between the L tone and its root node. This does not violate MAX τ—σ or MAX $\tau]_{\phi}$–σ because the tone is floating in the input. The output is given in (333) where the unstable stem has received a H tone. The floating L tone(s) create a downstepped H tone on *wáŋ*.

(332)	Phrase-level input: /c̤ɔ̤̀a̤ː ᴸwaŋ-kɐ̤ᴸ/ bone eye-OBL	(333)	Phrase-level output: c̤ɔ̤̀a̤ː ꜜwáŋ bone eye\OBL

(334) *Phrase level:* plural oblique case with unstable noun

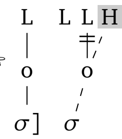
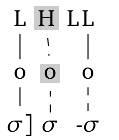
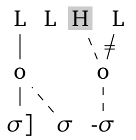
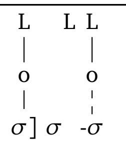
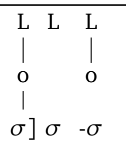
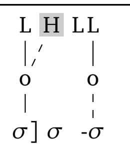
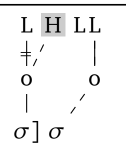
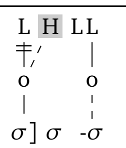
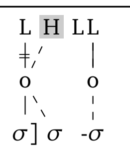
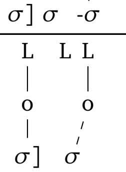
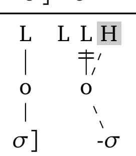
Input = (e)	MAX$_\omega$[V	OCP-L	MAX $\tau]_\phi$ | σ	τ ↑ σ	*o /| $\sigma\,\sigma$	*o o \\ / σ	*T T \\ / o	DEP-o	MAX τ | σ	MAX-V	$\tau]_\phi$ ↓ σ	DEP|	DEP-τ
a. ☞ 										*		**	*
b. 								*!				***	*
c. 					*!						*	***	*
d. 				*!								*	
e. 				*!*							*		
f. 				*!			*					**	*
g. 			*!						*	*		**	*
h. 			*!	*					*			**	*
i. 			*!						*			***	*
j. 		*!								*		*	
k. 	*!									*		**	*

Tableau (337) gives the phrase-level evaluation of the noun /^{L}waŋ/ when it is formed in the nominative singular instead of the oblique case above. The input has a L-toned word to the left in (335), an auxiliary shown by the square bracket in the tableau. The noun *wa*ŋ has a floating L tone; i.e., without a root node since it is an unstable noun. These two words form separate prosodic words which together form a p-phrase. The difference from Tableau (334) above is that there are no exponents of the oblique case. Somehow this noun needs to get a tonal specification to avoid violating $\tau \leftarrow \sigma$. Candidates (d–e) let the stem remain toneless, which therefore fatally violate this constraint. Deleting the entire stem, as in candidate (i), violates $\textsc{max}_{\omega}[\textsc{v}$ because the vowel is deleted and is ruled out. It would also violate $^{*}\textsc{cc}]_{\sigma}$ if the segments were shown. Candidate (h) inserts a root node so that the lexical tone can link to the stem. Because the preceding word is L-toned, this fatally violates OCP-L and is also excluded. There are several ways to avoid OCP-L violations. Candidates (f–g) merge the L tones. However, this violates $\textsc{max}\,\tau]_{\phi}\!-\!\sigma$ because these kinds of repairs involve deleting the linked L tone of the preceding word. Avoiding deletion by spreading its L tone is a solution to avoid OCP-L violation, as in candidate (b), but this is tone spreading and fatally violates $\underset{*}{\circ} \leq {\sigma \atop \sigma}$. The winner is therefore candidate (a), which repairs the OCP-L by inserting a H tone on the stem. Although this requires a root node insertion, it is the optimal candidate. The output is a downstepped H tone caused by the floating lexical L tone (336).

(335) Phrase-level input (nominative):
c-ɛ̀ ^{L}waŋ...
PFV-3SG eye

(336) Phrase-level output (nominative):
c-ɛ̀ ꜜwáŋ...
PFV-3SG eye

(337) *Phrase level:* singular nominative case with unstable noun

L L / o / σ] σ	MAX$_\omega$[V	OCP-L	MAX $\tau]_\phi$ / σ	τ → σ	*o / σ σ	*o o / σ	*T T / o	DEP-o	MAX τ / σ	MAX-V	$\tau]_\phi$ ← σ	DEP|	DEP-τ
a. ☞ L L H / o o / σ] σ								⋆				⋆⋆	⋆
b. L L / o / σ] σ					⋆!		⋆					⋆⋆	
c. L L / o / σ] σ					⋆!						⋆	⋆	
d. L L / o / σ] σ				⋆!							⋆		
e. L L / o / σ] σ				⋆!			⋆					⋆	
f. L L / o / σ] σ			⋆!				⋆		⋆			⋆⋆	
g. L L / o o / σ] σ			⋆!					⋆	⋆			⋆⋆⋆	
h. L L / o o / σ] σ		⋆!						⋆				⋆⋆	
i. L L / o / σ]	⋆!									⋆	⋆		

The Tableau in (340) gives the phrase-level evaluation of the unstable noun with a lexical floating H tone: ᴴd̪o̤ːl 'boy', which follows another H-toned word (338). The auxiliary is shown in a square bracket in Tableau (340). Since there are no adjacent L tones in this input, the main difference between the candidates is whether and how the unstable noun gets a tone. As has been seen in the other tableaux, inserting a root node is costly in Nuer. However, there are no better alternatives in order to link a tone to the noun. Candidate (f) drastically deletes the vowel of the noun so that there is no TBU in need of a tone. In this way, there is no toneless syllable which needs a tone. However, this fatally violates the constraint MAX$_{\omega}$[V since the unstable noun forms a prosodic word and its vowel is the left-most of this domain. Candidate (c), the input, and candidate (d) leave the noun toneless which fatally violate $\tau \leftarrow \sigma$. However, the latter candidate is worse since it links the lexical H tone to the preceding word violating also $\underset{*}{\mathrm{HL}} \geq \circ$. Candidate (b) and (e) provide a tone to the noun by linking the root node of the preceding word. Because the root node is associated to two syllables, it fatally violates $\underset{*}{\circ} \leq \genfrac{}{}{0pt}{}{\sigma}{\sigma}$ in candidate (b). Candidate (e) does not violate this constraint because it deletes the association line between the syllable and the root node of the preceding word. However, the latter candidate violates MAX $\tau]_{\phi}$–σ since the preceding tone is the only and rightmost linked tone of the p-phrase and loses. Therefore, the optimal candidate is candidate (a) which inserts a root node in order to link the lexical H tone to the noun. Note that the two adjacent H tones are fine because (i) the words form separate prosodic words and (ii) the constraint CUM-H is only ranked high at the word level. The output is the H-toned noun in (339).

(338) Phrase-level input (nominative):
cé̤ ᴴd̪o̤ːl...
PFV-1SG boy

(339) Phrase-level output (nominative):
cé̤ d̪ó̤ːl...
PFV-1SG boy

(340) *Phrase level:* singular nominative case with unstable noun

H H o σ] σ	MAX$_\omega$[V	OCP-L	MAX $\tau]_\phi$ σ	τ $\uparrow$ σ	*o / $\sigma\sigma$	*o o \ / σ	*T T \ / o	DEP-o	MAX τ σ	MAX-V	$\tau]_\phi$ $\downarrow$ σ	DEP|	DEP-τ
a. ☞ H H o o σ] σ								⋆				⋆⋆	
b. H H o σ] σ					⋆!		⋆					⋆⋆	
c. H H o σ] σ				⋆!							⋆		
d. H H o σ] σ				⋆!			⋆					⋆	
e. H H o σ] σ			⋆!				⋆		⋆			⋆⋆	
f. H H o σ]	⋆!									⋆	⋆		

9.7 Exceptions: suffixless stems

The analysis outlined in sections 9.5–9.6 accounts for the majority of the data. This section takes a look at some nouns with exceptional patterns.

As was shown in Table 7.15 in chapter 7, not all nouns get -*n̤i̤* in the plural oblique case. This group of unstable nouns fails to get this suffix and undergo stem-internal modifications in all inflected forms. The nouns are provided again in Table 9.7 below. These nouns are irregular in both the plural nominative and the plural oblique. In the nominative, two nouns fail to get a H or HL tone on the stems. In the oblique case, they have either a H, L, or HL tone.

SG	PL	PL OBL	Gloss
dɛ̂ˑl	dé̤t	dé̤ːt	‘sheep/goat’
ràːn	nâːt̪	nât̪	‘person’/‘Nuer’
jâŋ	hɔ́ˑk	hɔ̤̀ːk	‘cow’
cí̤e̤k	mɛ̤̀ˑn	mɛ̤́ːn	‘woman’
kwɛ̤́n	kwàn	kwâˑn	‘food’

Table 9.7: Irregular tone patterns of unstable stems in oblique case, plural

The second exception concerns four stable nouns. A noun is stable when it has a tone linked to the stem in the input. This second group of exceptional nouns behaves as stable because they get a plural suffix in the nominative and oblique case, and they are also immune to H tone epenthesis when they are positioned final in the p-phrase. They are only exceptional in the oblique case singular where they fail to get a suffix. Two nouns have a lexical H and HL tone, which are retained in the oblique form. The example in (341) shows the oblique construction of *bṳ́ˑk* which has a H tone also in a genitive construction. Thus, it does not get *-kɐ̤* as other stable nouns.

(341) bṳ́ˑk ‘Nuer god’
jâŋ bṳ́ɔ̤ːk
cow Nuer.god
‘the cow of the Nuer god’

The noun *tɔ̤̀t* ‘summer’ – repeated from (192) – also inflects for the oblique case by stem-internal modifications. This makes it similar to an unstable noun. However, it has more properties of being stable than unstable: when the plural is derived, it gets a suffix in the nominative (*tɔ̤̀t-nḭ́*). According to the analysis of this chapter, this would not be possible if it did not have a tone linked to the stem in the singular. Because this noun has a L tone, it is possible to see that it behaves stable concerning OCP-L repairs. As the example (342) shows, the L tone of the stem must be specified because H tone epenthesis targets the adjacent syllable, not *tɔ̤̀t* itself.

(342) Nominative: tɔ̤̀t
/gékɐ̤̀ tɔ̤̀a̤t/
gékɐ̤́ tɔ̤̀a̤t
next.to summer\OBL.SG
‘next to the summer’

The noun *gɔ̂ːk* 'monkey' is even more puzzling. In the oblique singular form, it gets a L tone on the stem instead of a suffix. Thus, it behaves as an unstable noun in this inflection. However, it behaves as stable because the plural form gets the suffix *-ní̤*. It also behaves as stable concerning OCP-L repairs because it is immune to H tone epenthesis and the preceding syllable gets the H tone (343).

(343) Nominative: gɔ̂ːk
/gékè̤ gɔ̀aˑk/
géké̤ gɔ̀aˑk
next.to monkey\OBL.SG
'next to the monkey'

Thus, the two groups presented in this section are exceptional stems. The first group concerns plural unstable stems which fail to get a *-ni̤* in the oblique plural, and their stem tones cannot be predicted from the examples of this study. The second group consists of stable nouns which fail to get the suffix *-ke̤* in the oblique singular form. Their stem tones behave as stable in other contexts.

I propose that the unstable plural nouns and the stable singular nouns have a Ø suffix in the oblique case which cannot be realized on the surface. This suffix blocks the appearance of *-ke̤* for singular stable stems in the oblique case and *-ni̤* for the unstable stems. The -Ø suffix makes it impossible for grammatical tones to link to the stem. The stable singular nouns already have a lexical tone specified in the input. Therefore, there are no toneless syllables which a grammatical tone can link to. The consequence of this is that the nouns appear with a lexical tone. This explains why they have different tones in the oblique case. The same applies to unstable stems in the plural.

Exceptional unstable plural stems

(344) 'food'
a. kwàn-Ø NOM.PL
b. kwâˑn-Ø OBL.PL
c. *kwâˑn-Ø-nì̤

Exceptional singular stable stems

(345) 'summer'
a. tɔ̤̀t SG
b. tɔ̤̀a̤t-Ø OBL.SG
c. *tɔ̤̀a̤t-Ø-ké̤

Some questions remain open. First, it is not clear why some of the unstable plural stems change tone in oblique plural while others do not. For example 'sheep/goat' does not change tone: *dé̤t* – *dé̤ːt*, but 'woman' does change: *mè̤ˑn* – *mé̤ːn*. Second, why does the stable noun *gɔ̂ːk* 'monkey' change to a L tone in the oblique singular? Some speakers gave another form of this noun with a suffix (346). With this pattern, it behaves exactly as a stable noun by keeping its stem tone and getting a L suffix.

(346) Alternative forms for gɔ̂ːk

a. ɟɔ̂ gɔ̂˙k-ɛ̤̀
behind monkey-OBL.SG
'behind the monkey'

b. lɔ̂˙c gɔ̂˙k-ɛ̤̀
heart monkey-OBL.SG
'the heart of the monkey'

In sum, the suffixless forms are exceptional because they are unpredictable concerning stem tones. They still have other properties which make it possible to group them as either unstable or stable stems (plural formation and OCP-L repair). The fact that they cannot receive a suffix seems related to their irregularity. The tentative proposal for this is that they get a zero suffix which blocks the oblique suffixes.

9.8 Summary and discussion

This chapter presented a Stratal OT analysis with layers of defectiveness which accounted for nominal inflection in Nuer. It provided essential insights into the interplay between tone and affixation. The most vital insight of the analysis is that suffix allomorphy can be derived serially by general phonological processes. The analysis showed how tone plays an essential role in inflection insofar as stems' tonal specification determines whether a noun will get a suffix or not. In this way, arbitrary distribution of suffixation classes independently motivates structural representations evaluated by three strata. This analysis saves the grammar from having inflection classes for each suffix pattern.

The type of data in this study depends on a serial evaluation where the exponents belong to different levels in the grammar. A parallel approach would make the wrong predictions. More concrete, if the plural suffixes (*n̤i̤* and a H tone) were simultaneously exposed to stems, the outcome would be that all stems get a H-toned suffix. This could not explain why some stems simply get a H tone in the plural, while other stems get a H-toned suffix. The serial derivation can capture that Nuer only has one *-n̤i̤*: It depends on the timing of the derivation whether a noun surfaces with a H-toned or a L-toned *-n̤i̤*. A H-toned *-n̤í̤* is the result of an early linking between the tone and syllable. This happens because the plural H tonal tree has to link to the suffix since it cannot link to stems which already have a tone, so-called stable stems. Later, the H-toned *-n̤í̤* cannot change anymore to L in the oblique case. A L-toned *-n̤ì̤* is the result of a late tonal association. At the stem level, the plural H tonal tree links to hybrid and unstable stems instead of linking to the suffix. This leaves *-n̤i̤* toneless when it comes to the phrase level. Here, the L tonal tree of the oblique case gets a chance to surface on *-n̤i̤*. In other words, the stratal OT analysis is more economical because only one lexical entry of the *-ni* suffix is needed. This can be considered a novel use of strata in that it can derive affix allomorphy. I argue that the serial approach is superior to a parallel approach. The main reason for this is that the latter would depend on two lexical entries of the same *-ni* suffix, a H-toned suffix lexically specified for stable nouns, and a toneless or L-toned suffix lexically specified for hybrid and unstable nouns.

Allomorphy which cannot be connected with, e.g., semantic or phonological properties of nouns is problematic in any framework which seeks to generate outputs from inputs via rules, constraints, or other grammatical building blocks because it requires an arbitrary part in the grammar. An analysis which can deduce allomorphy to predictable processes in, e.g., the phonology gives a great advantage over analyses which rely on arbitrary classes in the grammar.

The core of the analysis relies on representational enrichment in autosegmental structures. I introduced a bidirectional stem-affix defectiveness. The 'Generalized Nonlinear Affixation' (Bermúdez-Otero, 2011) predicts that non-concatenative morphology happens because of floating tones which appear without a segmental suffix. For Nuer, this would be non-concatenative exponence (floating tones) vs. concatenative exponence with suffixes. However, this type of defectiveness is not sufficient in Nuer to predict when a noun gets a suffix as opposed to when it undergoes tonal overwriting. The data require a bidirectional approach for defectiveness in that non-concatenative morphology applies when *both* stems and affixes are defective. Only this approach can derive the data in Nuer. The output depends on a serial interaction between the defectiveness of affixes with the defectiveness of stems (stable, hybrid, and unstable). Nuer is therefore a language for which non-concatenative morphology applies when both stems and affixes are defective (e.g., unstable stems and floating tonal affixes). This is an essential insight into the possible mechanisms of non-concatenative morpho-phonology which is prevalent in Western Nilotic languages.

The unstable stems presented in this analysis are especially puzzling. On the one hand, they behave as toneless because their surface tone depends on the surrounding material. That is, H tone epenthesis or grammatical tones show up on these stems. On the other hand, they are not completely toneless because they show up with a lexical tone (H, L, or HL) in the nominative. The solution to this was to let a lexical tone be accessible to the stem as a floating tone but which is also unable to link to the stem because it lacks a root node. In this way, grammatical tones can link to the stems of these nouns. The lexical tone shows up as a last resort when the stem has gone through all the strata in the grammar and has not been exposed to any grammatical tone. It was shown in chapter 7 that the unstable stems also behave 'unstable' in the nominative singular. With lexical L-toned stems, they will be subject to H tone epenthesis when they are adjacent to other L-toned words. This does not happen with the stable and hybrid stems. Therefore, the data support that lexical tones do not link to the stem syllable until the phrase level.

9.8.1 Alternative approaches

The idea of stress-dependent affixation is not new (Drachman et al., 1995; Kager, 1996; Mester, 1994: among others). To give some examples, the deverbal suffix *-al* in English can only attach to stems with final stress (*denýable* but *édit* → **édital*). In Drachman et al. (1995), they argue that the choice of allomorphy in Greek can be motivated by constraints on the prosody. In brief, they have an OT analysis where the lexicon feeds allomorphic forms of a morphological category. The allomorphs are then evaluated in candidate outputs where an optimal candidate is chosen, determined by prosodic constraints. For tone, Zimmermann (2016) has proposed tone-dependent affixation in Yucunany Mixtepec Mixtec. This is an analysis with defectiveness represented by syllable structure. The choice of tone-segment allomorphy is accounted for in an OT analysis which is similar in spirit to the current analysis. The morpheme /-yu/ only attaches to L-toned stems. In most contexts, it is not realized because it is structurally defective and lacks a syllable. The tone of this segment, therefore, attaches to the verbal stem. If its tone cannot link to a stem (the case of L-toned stems), then /-yu/ has to be realized. Her analysis works nicely for affixes.

If the analysis by Zimmermann were applied to Nuer, it would be possible to reflect the stem defectiveness with syllable structure in the following way: the stable stems would have a syllable linked to a lexical tone, the hybrid stems would have a syllable with a floating tone, and the unstable stems would lack a syllable entirely – consisting only of a floating tone. The advantage of such an analysis would be that root nodes are not needed. The representational differences can, therefore, be reduced to syllables and floating tones. However, a potential problem for such an approach is that Nuer words consist predominantly of monosyllabic words. If monosyllabic words lack a syllable, it means that default insertion of a syllable applies every time a speaker pronounces a noun in the nominative. The syllable forms a core part of the universal structure of the prosodic hierarchy, where syllables are dominated by feet, which again are dominated by prosodic words (Nespor and Vogel, 2007). In disyllabic words, it can be assumed that structures deviate from this by, e.g., having a weak layering as opposed to a strict layering. That is, they have extra-prosodic syllables which are not parsed in a foot (Itô et al., 1995). A deviation from this hierarchy and from the definition of the 'minimal word' (Hyman, 2006) would, however, be fatal in monosyllabic words where the syllable is the head of the structure. The prediction is then that a big portion of words in Nuer are prosodically defective. The question would then be how learners can have access to words which are defective at such a deep level.

In addition, this type of analysis where the defectiveness involves syllables instead of root nodes would make the wrong predictions regarding moraic structures. Under this analysis, the mechanism for the unstable stems to survive in the output would be to take the syllable of the suffixes. This would predict wrong outputs. Syllables dominate moras, and there is a three-way moraic distinction in lexical stems. Suffixes, on the other hand, are monomoraic. If the unstable stems took over the syllables of the suffixes, and therefore also the moraic structure of the suffixes, as opposed to just taking over the root node, the outcome would be the following: an unstable stem which is trimoraic such as *dɔ̤́ːr* 'tribe' would take over the monomoraic structure of *-kɛ̤* and be pronounced as monomoraic in the oblique case producing the incorrect form **dɔ̤̀r* instead of the trimoraic stem *dɔ̤̀ːr* tribe\OBL.SG.[3] To avoid this false outcome, it would have to be assumed that an additional operation is at work; for example, that the moras of the unstable stems are floating and link to the suffix syllable presumably by deleting the existing moras of the suffix. In the proposed analysis with root nodes, moraic structures are not an issue. For the unstable stems, the constraint MAX_{ω}[V determined the preference for stem vowels to be kept and suffixes to be deleted, generating correct outputs. Thus, defectiveness in Nuer is captured better with root nodes compared to an analysis with defective syllable structures.

The structural enrichment proposed here relies on register theory and the root node structure proposed by Yip (1989). An alternative analysis involves gradient structures where, e.g., the association lines between the three stem types could differ in numerical activity (see Zimmermann 2018). Although this might work for Nuer, a gradient approach involves a structural enrichment which would not be independently motivated in other parts of the phonology. Although there is also structural enrichment in the current analysis, root nodes are independently motivated because of how contour tones behave in Nuer. Second, a gradient approach would fail to capture the main idea behind the current analysis. Namely that affixes and stems interact in the way that if an affix can provide the necessary structure for a stem (a root node), a stem can be fully realized with a tone and the affix is no longer needed. Therefore, defective stems do not simply have a 'weaker' structure than stable stems. Instead, they are unstable in that they are looking for a host (an affix tone) in order to surface with a tone.

9.8.2 Assumptions on strata

The strata I proposed for Nuer correspond to the stem, word, and phrase levels in Bermúdez-Otero (2018). One point to note is that it is not as straight-forward to motivate these strata in a language with non-linear morphology, such as Nuer. In the approach I adopted by Bermúdez-Otero, a grammatical constituent is ascribed to either the stem level or the word level depending on properties of both the base and affix (Bermúdez-Otero, 2011). According to his definitions, the stem level consists of the stem (the root plus suffixes), while the word level comprises the stem plus prefixes. The phrase level is standardly the postlexical level for sentences. In Bermúdez-Otero (2018: 7), it is explicitly stated that "[t]he order of P-function application is thus intrinsically determined by morphosyntactic constituency". In this approach, strata are non-recursive, i.e., a stratum is only evaluated once in the phonology.

[3]There are some nouns which actually shorten in the oblique such as *kêːr* 'calabash plant' which has the oblique singular form *kɛ̤̀r*. This is, however, not frequent and certainly not a regular pattern. The most common process is a lengthening such as *bâ·r* 'lake' to oblique form *bàːr*.

First, the word is defined as a syntactically autonomous lexical item containing all the inflectional features required by its category. My proposal deviates from these assumptions by Bermúdez-Otero in that the oblique inflection does not happen until the phrasal level. If this category is the oblique case, the definition falsely predicts that the oblique exponents appear in the input at the word level in Nuer. However, I argue that it does make sense that these features appear at the phrase level instead of the word level because the oblique case appears when a noun is in a syntactic relation with another noun or preposition. Following this line of thought, words in Nuer cannot get case features before they enter the phrase level.

Second, according to the definition by Bermúdez-Otero (2018: 9), the root is the minimal acategorical lexical item. The stem is a lexical item specified for a syntactic category but must undergo further morphosyntactic operations before it is inflectable. In this analysis, the plural inflection at the stem level involves a H tonal tree as a plural marker corresponding to the definition of a stem. That is, the items are specified for a syntactic category 'noun', but need to undergo another operation before the inflection is complete. They do not become plurals until the word level where the second plural exponent appears: *-ni̤*. Although this analysis might be considered unusual because two plural markers appear at different strata, it is reasonable to assume that non-linear morphology does not follow the same order of affixes as linear morphology. This indicates that there might not be an intrinsic order for which stratum a floating tone belongs to in languages such as Nuer. In fact, my bidirectional approach to defectiveness predicts that affix material can occur at different strata, and in Nuer the plural markers appear as a suprasegmental exponent at the stem level and as a segmental exponent at the word level.

The difficulty in having intrinsically motivated strata is not only valid for Nuer. Most of the empirical evidence supporting Stratal OT comes from European languages such as English and Spanish. However, even in English, it is not always easy to determine which stratum an affix belongs to. For example, English has stress patterns which indicate recursiveness at the stem-level. Bermúdez-Otero refers to this as the 'stem-level syndrome'. Bermúdez-Otero (2012, 2013) argue that this is a consequence of stem-level constructs being listed nonanalytically or as whole forms in the lexicon. Word- and Phrase-level constructs are either unlisted or listed analytically. In other languages, especially understudied ones, there is empirical evidence supporting levels beyond the stem – word – phrase levels. This has been found in languages such as in Kimatuumbi (Odden, 1996) and Kinande (Jones, 2014). As Kiparsky (2015) points out, these are languages with exceptionally rich morphologies. The claim by Bermúdez-Otero (2018: 7) that strata are intrinsically determined by their morphosyntactic constituency is in fact difficult to apply for languages with non-linear phonology (see Paschen: 34 for a discussion of this in reduplication). Therefore, this analysis in Nuer shows that the morphosyntactic motivation for determining strata is not as clear-cut for non-linear morphology.

Chapter 10

Conclusion

This dissertation presented novel data on nominal tone in Nuer. It outlined intriguing interactions between lexical tone, OCP-L, and grammatical tone. The empirical part of this study showed the representation, distribution, and phonetic realization of lexical tone in Nuer as well as the phonetic manifestations of H tone epenthesis. By analyzing these data, the theoretical contribution captured how the different components, lexical tone, L tone restriction, and inflectional tone, interact serially. The next sections summarize and conclude the dissertation and address remaining open issues.

10.1 Summary and concluding remarks

I showed that Nuer has a rich tonal system in several aspects. On the surface, there is a phonetic contrast between H, M, L, and HL tones. In addition, the M tone alternates with a rising tone. Lexical tone was thoroughly examined in the phonology and phonetics. I claimed that Nuer has H, L, and HL tones underlyingly. These tones differ acoustically in speakers production. In the perception, HL and L tones show a clear-cut contrast in f_0 alignment and height. Despite the fact that Nuer speakers are generally not aware of speaking a tone language, participants proved to be sensitive to remarkably fine-graded alignment changes of tone.

Some of the complexity of underlying tonal structures is revealed in the tonotactics. The constraint OCP-L is active in Nuer, and in contexts where adjacent L tones are expected, a polar pattern arises. I claimed this results from H tone epenthesis, which inserts H tones in L tone sequences. This process exposes a contrast between what I call stable and unstable stems. Unstable stems are peculiar because they have a lexical tone, but it does not surface in many contexts such as in inflectional forms or sequences with OCP-L violations. If an unstable noun is L-toned and occurs with adjacent L tones, a H tone will be inserted on its stem. The floating lexical L tone manifests itself in the nominative case without OCP-L violations, or as a downstep on inserted H tones. That is, its floating L tone lowers the epenthesized H tone. Moreover, there are stable nouns which have a linked tone in the input. These nouns are immune to H tone epenthesis in certain prosodic positions. In cases with two adjacent L-toned stable nouns, a prosodic constraint will preserve the tone linked to the rightmost syllable of a p-phrase.

HL tones in Nuer are of two types: lexical and derived. The lexical HL tones appear on syllables independent of their vowel length. They do not trigger OCP-L violations when L tones follow. Derived HL tones were observed on utterance-final verbal stems. They arise under OCP-L violations. To capture these differences, I adopted tonal root nodes proposed by Yip (1989). The lexical HL tones are unitary HL tones associated to one root node, whereas cluster HL tones are associated to two root nodes. The fact that most HL tones in Nuer are unitary tones makes the tone system of Nuer more similar to East and Southeast Asian tone languages, compared to e.g., Bantu languages.

The root nodes are an essential part of the main analysis presented in chapter 9. In the last part of this dissertation, I showed that the tonal distinctions in the stems fall naturally out of case and number inflections. Nuer has the suffixes *-kɛ̤* and *-ni̤* which concatenate with some stems, but not all. While previous studies have treated the distribution of these suffixes as allomorphy, this study showed that the data is fairly regular. More importantly, I showed that suffixation relates directly to the stable – unstable distinction. That is, I proposed that case and number are marked by floating tones in addition to the segmental suffixes. Instead of arbitrary noun classes, I proposed that all stems get exposed to the same suffixes. The nature of the stems determines whether the suffix will get a tone and be realized, or remain toneless and be deleted.

In a nutshell, when a stable stem gets a suffix, floating tones can dock onto it because the stem is already specified for tone. Unstable stems, on the other hand, lack a root node. When they get a suffix and an inflectional tone, the inflectional tones goes on the stem instead of the suffix. The suffix cannot get a tone without violating high-ranked constraints against tone insertion, association line crossing, and tone spreading. The optimal output is, therefore, to delete the suffix. This analysis relies on a bidirectional defectiveness of affix material (floating tones and toneless suffixes) and stems which lack root nodes.

The patterns of inflection also depend on a serial derivation. The cyclic nature of the analysis could capture why there is only one *-ni̤* suffix, but it surfaces as either H- or L-toned. A H-toned *-ní̤* results from an early association between the plural H tonal tree and the suffix. This is possible for stable stems which already have a stem tone. Later, no other floating tone can overwrite it, and it stays H in the oblique case. The L-toned *-ni̤* results from a late association. When the plural H tonal tree and this suffix appear with unstable nouns, the H tone will not go on the suffix, but on the stem. The reason for this is that unstable nouns need a stem tone. This leaves a toneless *-ni̤* which is available to link to the oblique L tonal tree later. The strata make these interactions transparent at the intermediate levels of the grammar.

Perhaps the most vital outcome of this dissertation is how prominent the function of tone is in the grammar. There are several cases in which a nominative form differs from an oblique form by a tonal contrast alone. For example, a change from HL to L tone can mark a category as with the noun *kâl* 'fence' which has the oblique form *kàl*. By foregrounding tone, I showed that it can take the workload of suffix distribution by letting general phonological processes derive case and number inflection at different strata.

10.2 Open issues and directions for future work

10.2.1 Downstep

The analysis of this thesis relied on enriched representation of tonal architecture in autosegmental phonology. Chapter 5 mentioned that the root node structure by Yip (1989) used in this study is a simplified representation of a featural specification of tone used in register theory (cf. Hyman, 1993; Pulleyblank, 1986; Yip, 1990, 1995; Snider, 1999) where tonal features are hierarchically organized. In this theory, atomic features such as H and L are decomposed into binary features. The Tone bearing Unit contains both a tonal root node and a subordinated tonal node. The former denotes a register (e.g., ± Upper), while the latter denotes a tone (e.g., H, L).

While this architecture was not used in the analysis, it should be noted that having register tones is not incompatible with the current analysis. On the contrary, a key function of Register Theory is to capture the iterative nature of downstep which is widely attested in, e.g., Bantu languages, where it lowers the register of a sequence of tones within a given domain. In fact, there are many instances of floating L tones in Nuer. As I outlined in section 9.2.1, only unlinked L tones induce downstep in Nuer. In addition, linked L tones induce automatic downstep. In chapter 3, I showed that the L component of HL tones induced automatic downstep on following H tones. Also, in chapter 6, I showed that the HL tone which appears on the verbal stem is downstepped because it is at a lower level than preceding H tones. There were additional instances of downstep in this study which could not be examined further because it was beyond the scope of this dissertation. Some examples of such instances are shown below.

First, Faust and Grossman (2015) reported that the topicalizer ɛ with the plural form *k*ɛ (also referred to as a copula) introduces downstep on the following tones. This study confirms the effect of downstep in such constructions when comparing constructions without ɛ (347) with constructions containing ɛ (348).

(347) No downstep
gwár pùːr-ɛ́ ɟɛ̀
father dig-CP.3.SG 3.SG
'My father is making Manuel dig.'

(348) Downstep
cì gwár ɛ̀ ꜜpɔ́ːr-ɛ̀
PFV father 3.SG dig.CP.3.SG
'My father dug it for him/towards him.'

It is unclear whether downstep occuring in constructions such as (348) above have a syntactic function, or whether this is simply a phonological phenomenon where the topicalizer happens to comes with a floating L tone. In any case, downstep in Nuer appears to have different functions and is a topic for future research.

10.2.2 M tones

Another question which remains open concerns the underlying compositions of lexical M-toned nouns. Some nouns appeared with a lexical M tone in this study, and there are several possibilities for what the lexical M tones look like underlyingly in Nuer. They could be L tones with an upstep, H tones with a downstep, or simply an underlying M tone. In register theory, M tones are often analyzed as a tone decomposed into a high register with a L root node tone, or a low register with a H root node tone. Phonetically, lexical M tones are on the same level as L-toned nouns which have been subject to H tone epenthesis. They differ in that they are realized with a rising tone sentence-initially, and more importantly, that their M tones are not an effect of H tone epenthesis.

Data indicate that lexical M tones involve floating tones. First, it is possible that M tones involve a floating L tone because the following tones are lower. For example in (349), the H-toned suffix after the M tone of the stem is realized at approximately the same f_0 level as the M tone: d̪ɔ̄ːl-ḭ̄. This lowering might be due to a downstep, however it could also be due to final lowering since the word is final in the utterance.

(349) d̪ɔ̄ːl-ḭ́
boy-PL.OBL

Not only M-toned nouns induce lowering on following targets. Recall from chapter 3 that M tones on verbs induced lowering on following H tones (in sentence-type *M_%*).

Second, lexical M tones induce a downstepped HL tone on the L-toned verbal stem *nɛ̀ˑn*. In constructions with M-toned nouns as in (350), the L-toned verbal stem gets a downstepped HL tone. The same was observed after L-toned nouns because of the OCP-L as in (351) – repeated from (41) and (43) in chapter 2 – or after unstable L-toned nouns, which are also raised to H (352). As was shown in chapter 5, the verb stem is L-toned after nouns with an underlying H or HL tone (353).

(350) Lexical M tones

a. hē̤n c-é̤ cɔ̤̄ˑw ↓nɛ̂ˑn
1SG PFV-1SG bone\PL see
'I have seen the bones.'

b. hē̤n c-é̤ twɔ̤̄ˑt ↓nɛ̂ˑn
1SG PFV-1SG wild.goose see
'I have seen the wild goose.'

(351) Stable L tones

a. hē̤n c-é̤ nè̤ˑn nɛ̂ˑn
1SG PFV-1SG mirror see
'I have seen the mirror.'

b. hē̤n c-é̤ cɔ̤̀a̤ː nɛ̂ˑn
1SG PFV-1SG bone see
'I have seen the bone.'

(352) Unstable L-toned noun

c-ɛ̀ ↓máːr nɛ̂ˑn
PFV-3SG relationship see
'(S)he has seen the relationship.'

(353) Lexical H-toned noun

hē̤n c-é̤ tét nɛ̀ˑn
1SG PFV-1SG hand see
'I have seen the hand.'

The data above indicate two processes. First that lexical M tones appear to induce downsteps, and second that they also induce a HL tone on L-toned verbal stems. The HL tone on the verb is downstepped in all examples, i.e., (350)–(352). This was measured in chapter 6 and I assume that the downstep is automatic and induced by a linked L tone in cases such as (351) but non-automatic and induced by an unlinked tone in cases such as (352). The question remaining open is what the source of the HL tone and its downstep is in constructions with a lexical M tone in (351). Recall from chapter 5 that a HL tone on the verb *nɛ̀ˑn* appears in two contexts. One is because of OCP-L violations after syllables with a linked L tone, as in (351), while the other is after unstable L tones which are subject to H tone epenthesis, as in (352). In the latter case, I assumed that the epenthesized H tone links to both the unstable noun and the verbal stem (see also section 10.2.3 for more on this).

I exclude the option that the HL tone on the verbal stem after lexical M tones is due to OCP-L violations. If this were the case, lexical M-toned nouns would involve an underlying *linked* L tone, which is for some reason phonetically upstepped to a M level: *↑twɔ̤̀ˑt nɛ̂ˑn*. This is improbable because the lexical M-toned nouns do not trigger violations of the OCP-L in any other context and are invariably M, except for in sentence-initial positions where they can have a low-high allotone. If they would have a linked L tone, these nouns would trigger OCP-L violations in other contexts. In this sense, they pattern with H- and HL tones, and therefore I assume that they have a H tone in their underlying specification, which makes them insensitive to OCP-L violations.

Thus, a more probable explanation which captures why these nouns surface as M and trigger a HL tone on the verb, without inducing OCP-L violations, is that they have a floating LH contour tone. If both the L and the H tones are floating in the underlying specification, these two tones somehow surface as a M tone except for in sentence-initial position where the rising allotone is realized. This simplification could be a phonetic effect or a phonological rule against rising tones in sentence-medial positions. The hypothesis is that the floating H tone of lexical M tones can also link to the verb stem just as the epenthesized H tone links to both unstable L-toned nouns and the verbal stem.

In sum, more data should be gathered on lexical M tones in order to clarify their underlying composition. From the available data in this study, it is possible that they involve a floating LH contour tone. The H tone can also link to other syllables such as the L-toned verbal stem, and the L tone induces a downstep. In sentence-initial position, both tones are realized as a rising tone while in sentence-medial position they are realized as a M tone. The next section shows a short OT-analysis of how H tone epenthesis works on the verbal stem with unstable L tones creating the HL tone and how it works when a possessive marker intervenes.

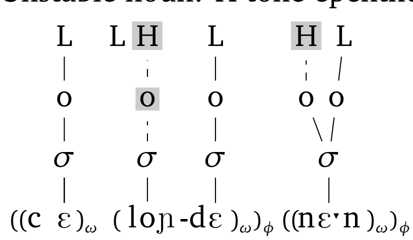
10.2.3 H tone epenthesis in utterances

Section 5.5 presented autosegmental structures of OCP-L repairs in the nominative case. In chapter 9, H tone epenthesis applied on the edges of the analyzed constructions, and some questions are left open concerning how H tone epenthesis in p-phrase medial positions of full utterances would be implemented in the OT analysis of the last chapter. This concerns especially data with possessive markers.

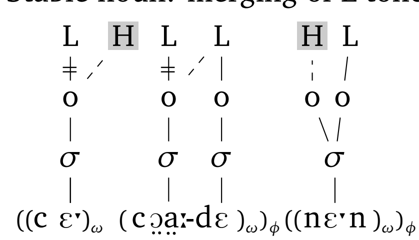
When the L-toned possessive marker *-dɛ̀* appears next to a L-toned noun, stable nouns are not subject to H tone epenthesis. Thus, on the surface, there is a L-L sequence which is not repaired by H tone epenthesis. In chapter 5, the proposal was that these L tones merge. The question is how this comes together with the OT analysis of the previous chapter. To repeat, the unstable noun gets H tone epenthesis as expected in constructions with unstable L-toned nouns (354). This contrasts with the repair of stable nouns, which instead merge the L tones (355). The details of how these repairs work in OT is given below.

OCP-L repairs

(354) Unstable noun: H tone epenthesis



(355) Stable noun: merging of L tones



For cases where nouns appear p-phrase medially, four constraints are needed in addition to the ones presented in the previous chapter. The constraint in (356) militates against tones linked to root nodes of different types within a prosodic word: an epenthetic tonal root node and an input tonal root node. As the analysis in the previous chapter showed, tone spreading in Nuer is avoided by high-ranked constraints. For example, toneless suffixes and unstable nouns never get their tone from neighboring syllables. However, tone spreading does occur in Nuer when unstable nouns get an epenthesized H tone and a defective L-toned verb follows. That is, the verb stem *nɛ˙n* 'see' gets a HL tone in two contexts: first, when *nɛ˙n* follows unstable L-toned nouns which are subject to H tone epenthesis – see e.g. (352) of the previous section – and, second, when it follows underlying L-toned syllables as in (354)–(355). The ranking of this constraint captures how the spreading of the inserted H tone can happen across prosodic word boundaries; i.e., between a noun and a verb, but not within this domain. Thus, this prohibits tone spreading with an inserted root node in smaller domains, such as between a possessive marker and an unstable noun, or between a stable noun and its suffix.

Furthermore, the constraint in (357) militates against toneless roots and ensures that stems such as the verb *nɛ˙n*, which have an empty root node in the input, get a tone in the output. This constraint must be low ranked at the stem and word level so that the verbal stem remains with an empty root node until the phrase level.

(356)
$$\begin{array}{c} *\mathrm{T} \\ / \quad \backslash \\ {}_{\omega}(\boxed{\mathrm{o}}\ \mathrm{o}) \end{array}$$
Assign a violation mark for every pair of root nodes o_1 and o_2 of different type (±epenthetic) within a prosodic word which are associated to a tone.

(357)
$$\begin{array}{c} \mathrm{T} \\ \uparrow \\ o \end{array}$$
Assign a violation mark for every root node which is not associated to a tone.

Moreover, in constructions such as (355) above where a stable L-toned noun appears p-phrase-medially, the most efficient repair would be to insert a H tone on the L tone in the middle: L#L-L → L#H-L. Instead, the L tones merge and the output is H#L-L. This is captured by the constraint in (358) which is ranked above the constraint MAXτ—σ in chapter 9. The proposed constraint in (358) militates against tones which are inserted in a p-phrase-medial position and is a mirror constraint of ALIGN-constraints. This constraint is mostly superfluous for the data in the previous chapter because more general faithfulness constraints accounted for where H tone epenthesis would appear. Also, H tone epenthesis only occurred at the edges in the winning candidates of that chapter.[1]

(358)
$$\begin{array}{c} *\boxed{\mathrm{T}} \\ | \\ [..\sigma..]_{\phi} \end{array}$$
Assign a violation mark for every epenthetic tone linked to a p-phrase-medial syllable.

Finally, the constraint IDENT-L in (359) is needed which militates against L-toned syllables in the input surfacing with a H tone. This is higher ranked than the constraint in (358), ensuring that (i) stable L-toned nouns can be repaired by merging L tones because they do not lose their

[1]Concretely, the constraint in (358) would only be violated in candidate (b) in Tableau (334) of chapter 9 where H tone epenthesis appears on the stem followed by a suffix. Since this is a losing candidate, the outcome would not change by adding this constraint in the analysis.

L tone feature, and (ii) unstable nouns can get H tone epenthesis even in a p-phrase medial position because they do not have L tones in the input. Without the ranking of IDENT-L above the constraint against p-phrase-medial epenthetic tones, H tone epenthesis would never occur p-phrase medially. At the same time, it makes it difficult for stable L-toned nouns to surface with a different tone. In chapter 9, the constraint IDENT-L would be violated in the tableaux where L-toned stable nouns get H tone epenthesis. Therefore, it is crucial that IDENT-L is ranked below OCP-L. With this ranking, none of the winners of the previous chapters are affected.[2]

(359) IDENT-L

Assign a violation mark for every input syllable node S_1 linked to a L tone that corresponds to an output syllable node S_2 linked to a tone with a different specification than L.

A minor adjustment is needed concerning DEP-τ, which referred to inserted tones or root nodes. This constraint has to be divided into the two more specific constraints DEP-L and DEP-H which refer to inserted L tones and L tonal trees, or H tones or H tonal trees, respectively. This is necessary to derive the correct winner with unstable L-toned nouns with a H-toned possessive marker. In chapter 9, this constraint splitting does not affect any of the winning candidates because there was mainly H tone epenthesis. The only candidate which involved L tone epenthesis on the phrase level was candidate (b) in Tableau (297). Even with DEP-L and DEP-H, this candidate would lose because of higher-ranked constraints.

The OT-tableaux for the most tricky structures of section 5.5 are presented below – see (86)–(87) for references. Only the phrase-level stratum is shown, and the structures correspond to outputs at the word level. In Tableau (360), the input is an utterance with four L-toned words in a row. The noun is stable with a L-toned possessive marker. Together, these two syllables form a prosodic word. The verbal stem has a L tone with an empty root node. The input (candidate h) violates the OCP-L three times and is ruled out. Candidates (e–f) only partially repair the OCP-L and are also ruled out. Candidates (b–c) apply the most efficient repair by inserting a H tone in the middle of the p-phrase on the stable noun, violating the constraint against p-phrase-medial inserted tones. Candidate (c) is excluded because it does not delink the L tone of the noun which leads to a contour tone fatally violating $*\mathrm{HL} \backslash o$. The constraint against p-phrase-medial inserted tones in (358) determines that candidate (a) wins over (b). The L tone of the stable noun is delinked and associates to the possessive marker. This way, it does not violate the OCP-L. The auxiliary and the verbal stem gets a H tone to avoid violating the OCP-L. This involves a non-fatal violation of ID-L on the auxiliary. The H tone on the verbal stem also serves to avoid a violation of the constraint in (357) against empty root nodes.

[2] For example, candidate (b) in Tableau (312) of the previous chapter loses because it violates MAX τ — σ. The constraint IDENT-L would also be violated because a L tone is delinked and the syllable gets a H tone, but the outcome of the derivation would be the same.

(360) *Phrase level:* nominative case with hybrid noun

L L L L / o o o o o / $((\text{c ɛ˙})_\omega$ $(\text{cɔ̤a̤ː -dɛ})_\omega)_\phi$ $((\text{n ɛ˙n})_\omega)_\phi$	OCP-L	MAX $\tau]_\phi$ — σ	*T /\ $_\omega$(o o)	$\tau \uparrow \sigma$	*o /| $\sigma\sigma$	*T T \/ o	*o o \/ σ	T ↑ o	ID-L	DEP-O	*T | $[..\sigma..]_\phi$	MAX τ — σ	MAX-V	$\tau]_\phi$ ← σ	DEP|	DEP-τ
a. ☞ L H L L H L / o o o o o / $((\text{c ɛ˙})_\omega$ $(\text{cɔ̤a̤ː -dɛ})_\omega)_\phi$ $((\text{n ɛ˙n})_\omega)_\phi$									1			2			3	2
b. L L H L H L / o o o o o / $((\text{c ɛ˙})_\omega$ $(\text{cɔ̤a̤ː -dɛ})_\omega)_\phi$ $((\text{n ɛ˙n})_\omega)_\phi$									1		1!	1			2	2
c. L L H L H L / o o o o o / $((\text{c ɛ˙})_\omega$ $(\text{cɔ̤a̤ː -dɛ})_\omega)_\phi$ $((\text{n ɛ˙n})_\omega)_\phi$						1 !			1						2	2
d. L H L L H L / o o o o o / $((\text{c ɛ˙})_\omega$ $(\text{cɔ̤a̤ː -dɛ})_\omega)_\phi$ $((\text{n ɛ˙n})_\omega)_\phi$		1 !		1		1						2			3	2
e. L H L L H L / o o o o o / $((\text{c ɛ˙})_\omega$ $(\text{cɔ̤a̤ː -dɛ})_\omega)_\phi$ $((\text{n ɛ˙n})_\omega)_\phi$	1 !		1			1						1			3	2
f. L H L L H L / o o o o o / $((\text{c ɛ˙})_\omega$ $(\text{cɔ̤a̤ː -dɛ})_\omega)_\phi$ $((\text{n ɛ˙n})_\omega)_\phi$	1 !											1			2	2
g. L H L L L L / o o o o o / $((\text{c ɛ˙})_\omega$ $(\text{cɔ̤a̤ː -dɛ})_\omega)_\phi$ $((\text{n ɛ˙n})_\omega)_\phi$	1 !								1			2			3	2
h. L L L L / o o o o o / $((\text{c ɛ˙})_\omega$ $(\text{cɔ̤a̤ː -dɛ})_\omega)_\phi$ $((\text{n ɛ˙n})_\omega)_\phi$	3!							1								

In Tableau (361), the input is an unstable L-toned noun flanked between the L-toned auxiliary and the L-toned verb. The obvious position to apply H tone epenthesis is on the unstable noun where it does not infer faithfulness violations. Thus, the interesting question is how the verbal stem gets a H tone. Note that the input (candidate f) does not violate the OCP-L because there is a toneless syllable in between the L tones. Still, this is ruled out because of the toneless syllable violates $\tau \leftarrow \sigma$. Thus, the unstable noun and the empty root node of the verb need a tone. They cannot get a L tone because this will create OCP-L violations (candidate h). Inserting H tones at the left and right side will infer various faithfulness violations (candidate g). If a H tone is inserted on the verbal stem which then spreads onto the unstable noun, the insertion of a root node can be avoided. However, this fatally violates the constraint against tone spreading from a root node (candidate e).

The best option is to insert a root node and a H tone on the unstable noun. Candidate (d) is out because the root node of the verb remains empty, violating the constraint in (357) against empty root nodes. The remaining choice is between candidates (a–c). Candidate (c) is excluded because two H tones are inserted, violating DEP-H twice. The winner is candidate (a) where only one H tone is inserted which spreads onto the root node of the verb. This kills two birds with one stone because the H tone can link to both the toneless syllable of the noun and the toneless node of the verb. Since the verbal stem is not within the same pw-word-domain as the noun, this candidate does not violate the constraint in (356) against a tone linked to different root nodes in a pw-domain. Candidate (a) wins over candidate (b) which inserts a L tone on the verbal stem, fatally violating DEP-L.

(361) *Phrase level:* singular nominative case with an unstable noun

L L L o o o $((\text{c}\varepsilon)_\omega\ (\text{loɲ})_\omega)_\phi\ ((\text{nɛ·n})_\omega)_\phi$	OCP-L	MAX $\tau]_\phi$ / σ	*T /\ $_\omega$(o o)	$\tau \rightarrow \sigma$	*o /| $\sigma\sigma$	*T T \/ o	*o o \/ σ	T $\rightarrow$ o	ID-L	DEP-O	*T | [..σ..]$_\phi$	MAX τ | σ	MAX-V	$\tau]_\phi \leftarrow \sigma$	DEP|	DEP-H	DEP-L
a. ☞ L L H L o o o o $((\text{c}\varepsilon)_\omega\ (\text{loɲ})_\omega)_\phi\ ((\text{nɛ·n})_\omega)_\phi$										1	1				3	1	
b. L L H L L o o o o $((\text{c}\varepsilon)_\omega\ (\text{loɲ})_\omega)_\phi\ ((\text{nɛ·n})_\omega)_\phi$										1	1				3	1	1!
c. L L H H L o o o o $((\text{c}\varepsilon)_\omega\ (\text{loɲ})_\omega)_\phi\ ((\text{nɛ·n})_\omega)_\phi$										1	1				3	2 !	
d. L L H L o o o o $((\text{c}\varepsilon)_\omega\ (\text{loɲ})_\omega)_\phi\ ((\text{nɛ·n})_\omega)_\phi$								1!		1	1				2	1	
e. L L H L o o o $((\text{c}\varepsilon)_\omega\ (\text{loɲ})_\omega)_\phi\ ((\text{nɛ·n})_\omega)_\phi$					1 !									1	2	1	
f. L L L o o o $((\text{c}\varepsilon)_\omega\ (\text{loɲ})_\omega)_\phi\ ((\text{nɛ·n})_\omega)_\phi$				1 !				1						1			
g. L H L H L o o o o $((\text{c}\varepsilon)_\omega\ (\text{loɲ})_\omega)_\phi\ ((\text{nɛ·n})_\omega)_\phi$		1 !							1	1		1			4	2	
h. L L L L o o o o $((\text{c}\varepsilon)_\omega\ (\text{loɲ})_\omega)_\phi\ ((\text{nɛ·n})_\omega)_\phi$	2 !							1		1	1				2		1

Tableau (362) shows the same constructions as in the previous Tableau with a L-toned possessive marker. Splitting the DEP-τ constraint into DEP-H and DEP-L does not determine the winner for this construction and the more general constraint is shown for convenience.

The input (candidate j) violates OCP-L and is out. As in the previous Tableau, the best solution is to insert a H tone in the middle on the unstable noun since this is not linked to a tone in the input, as opposed to tone spreading in candidates (b–c). Inserting H tones on underlying L tones violates various faithfulness constraints. Therefore, candidate (a) wins. The H tone on the root node of the verb is necessary to avoid violating the constraint against toneless nodes, and it cannot stay toneless as in candidates (h–j). Also, the inserted tone on the verbal stem has to be H so that the OCP-L is not violated.

Note that, first, verbal stems cannot get a H tone through tone spreading of the epenthesized H tone since this would involve a crossing of association lines (recall the constraint against crossing of association lines in chapter 9 which is always undominated in Nuer). Second, another candidate similar to (a) is not shown for reasons of space. It would be possible that the root node of the verb gets a specification through tone spreading from the possessive marker, instead of inserting a H tone (in addition to the H tone on the verb). Such a candidate would be ruled out by the constraint against tone spreading at $\underset{*}{\sqsubset} < \genfrac{}{}{0pt}{}{\circ}{\circ}$, which should be ranked above DEP-τ – see the Tableaux of the word levels in the previous chapter.

(362) *Phrase level:* singular nominative case with unstable noun + L-toned possessive m.

Input = (j)	OCP-L	MAX $\tau]_\phi$ / σ	*T /\ $_\omega$(o o)	τ ↑ σ	*o /| $\sigma\sigma$	*T T \/ o	*o o \/ σ	T ↑ o	ID-L	DEP-O	*T | [..σ..]$_\phi$	MAX τ | σ	MAX-V	$\tau]_\phi$ ↓ σ	DEP|	DEP-τ
a. ☞ L L H L H L; o o o o o; ((c ɛ)$_\omega$ (l o ɲ -dɛ)$_\omega$)$_\phi$ ((n ɛˑn)$_\omega$)$_\phi$										1	1				3	2
b. L H L L H L; o o o o; ((c ɛ)$_\omega$ (l o ɲ -dɛ)$_\omega$)$_\phi$ ((n ɛˑn)$_\omega$)$_\phi$					1!				1			1			3	2
c. L H L L H L; o o o o o; ((c ɛ)$_\omega$ (l o ɲ -dɛ)$_\omega$)$_\phi$ ((n ɛˑn)$_\omega$)$_\phi$			1 !						1	1		1			4	2
d. L H L L H H L; o o o o o; ((c ɛ)$_\omega$ (l o ɲ -dɛ)$_\omega$)$_\phi$ ((n ɛˑn)$_\omega$)$_\phi$		1!							1	1		2			5	3
e. L L L H L; o o o o o; ((c ɛ)$_\omega$ (l o ɲ -dɛ)$_\omega$)$_\phi$ ((n ɛˑn)$_\omega$)$_\phi$	2!									1					3	1
f. L H L L H L; o o o o o; ((c ɛ)$_\omega$ (l o ɲ -dɛ)$_\omega$)$_\phi$ ((n ɛˑn)$_\omega$)$_\phi$	1 !								1	1		1			4	2
g. L H L L H L; o o o o o; ((c ɛ)$_\omega$ (l o ɲ -dɛ)$_\omega$)$_\phi$ ((n ɛˑn)$_\omega$)$_\phi$	1 !					1				1					4	2
h. L L L L; o o o o; ((c ɛ)$_\omega$ (l o ɲ -dɛ)$_\omega$)$_\phi$ ((n ɛˑn)$_\omega$)$_\phi$	2 !				1			1							1	
i. L H L L L; o o o o; ((c ɛ)$_\omega$ (l o ɲ -dɛ)$_\omega$)$_\phi$ ((n ɛˑn)$_\omega$)$_\phi$	1 !				1			1	1			1			2	1
j. L L L L; o o o o; ((c ɛ)$_\omega$(l o ɲ -dɛ)$_\omega$)$_\phi$((n ɛˑn)$_\omega$)$_\phi$	1 !			1				1								

Finally, Tableau (363) shows an unstable L-toned noun with a H-toned possessive marker. The input, candidate (h), violates the constraint $\tau \leftarrow \sigma$ since the unstable noun remains toneless in the output. It has to get a H tone to avoid violating OCP-L. Candidate (j) is therefore ruled out because it gets a L tone. Violations of OCP-L could be avoided by inserting a H tone on each side of the noun as in candidates (c–d). This is excluded because it fatally violates either $\underset{*}{\mathrm{HL}} \succ \mathrm{o}$ (candidate d) or IDENT-L (candidate c). Getting a tone through spreading from the root node of the possessive marker is also excluded because it fatally violates $\underset{*}{\circ} \leq {}^{\sigma}_{\sigma}$ (candidate e).

Thus, the choice stands between candidate (a) and (b) where a H tone has been inserted on the unstable noun and either a L or a H tone on the verbal stem. Candidate (a) wins because inserting a H tone is more expensive than inserting a L tone. Thus, the verbal stem surfaces with a L tone because a H tone is not needed in relation to the OCP-L, and there is a syllable intervening between the verbal stem and the noun which makes it impossible to spread the inserted H tone of the noun without crossing association lines.

(363) *Phrase level:* singular nominative case with stable noun + possessive m.

Input = (h)	OCP-L	MAX $\tau]_\phi$ / σ	*T /\ $_\omega$(o o)	τ ↑ σ	*o /| $\sigma\,\sigma$	*T T \/ o	*o o \/ σ	T ↑ o	ID-L	DEP-O	*T | [..σ..]$_\phi$	MAX τ | σ	MAX-V	$\tau]_\phi$ ↓ σ	DEP|	DEP-H	DEP-L
a. ☞ L L H H L L; ((cɛ)$_\omega$ (lɔɲ-dɛ̤)$_\omega$)$_\phi$ ((nɛ·n)$_\omega$)$_\phi$										1	1				3	1	1
b. L L H H H L; ((cɛ)$_\omega$ (lɔɲ-dɛ̤)$_\omega$)$_\phi$ ((nɛ·n)$_\omega$)$_\phi$										1	1				3	2!	
c. L H L H H L; ((cɛ)$_\omega$ (lɔɲ-dɛ̤)$_\omega$)$_\phi$ ((nɛ·n)$_\omega$)$_\phi$									1!	1		1			4	2	
d. L H L H H L; ((cɛ)$_\omega$ (lɔɲ-dɛ̤)$_\omega$)$_\phi$ ((nɛ·n)$_\omega$)$_\phi$						1!				1					4	2	
e. L H L H H L; ((cɛ)$_\omega$ (lɔɲ-dɛ̤)$_\omega$)$_\phi$ ((nɛ·n)$_\omega$)$_\phi$					1!				1			1			3	2	
f. L L H L; ((cɛ)$_\omega$ (lɔɲ-dɛ̤)$_\omega$)$_\phi$ ((nɛ·n)$_\omega$)$_\phi$					1!			1							1		
g. L H L H L; ((cɛ)$_\omega$ (lɔɲ-dɛ̤)$_\omega$)$_\phi$ ((nɛ·n)$_\omega$)$_\phi$					1!			1	1			1			2	1	
h. L L H L; ((cɛ)$_\omega$ (lɔɲ-dɛ̤)$_\omega$)$_\phi$ ((nɛ·n)$_\omega$)$_\phi$				1!				1									
i. L L H H L; ((cɛ)$_\omega$ (lɔɲ-dɛ̤)$_\omega$)$_\phi$ ((nɛ·n)$_\omega$)$_\phi$			1!							1		1			3	1	
j. L L H H L; ((cɛ)$_\omega$ (lɔɲ-dɛ̤)$_\omega$)$_\phi$ ((nɛ·n)$_\omega$)$_\phi$	1!									1					3	1	

In sum, the analysis of chapter 9 also works for utterances in Nuer with some additional constraints which are compatible for all derived constructions. It shows more mechanisms of the OCP-L violations. Namely, H tone epenthesis is avoided in a p-phrase medial position in Nuer, unless it goes on unstable nouns which are not linked to a tone in the input. This avoidance leads to another repair consisting of merging underlying L tones which are p-phrase-medial. This captures why the OCP-L is often repaired in 'inefficient' ways by inserting a H tone on the edge, and merging two L tones: /L#L-L/ → H#L-L instead of simply inserting the H tone in the middle: /L#L-L/ → *L#H-L. For toneless syllables, inserting a H tone p-phrase-medially is preferred over other OCP-L repairs since it does not infer faithfulness violations.

In addition, tone spreading in Nuer is mostly avoided and is only possible in rare cases. One such case involved defective L-toned verbal stems such as *nɛ̀ˑn* 'see'. This verb can get a HL tone by sharing the epenthesized H tone of unstable nouns. However, this kind of spreading is only possible across prosodic word domains and cannot occur within this domain.

Bibliography

Aissen, J. (2003). Differential object marking: Iconicity vs. economy. *Natural Language and Linguistic Theory 21*, 435–483.

Andersen, T. (1990). Vowel length in Western Nilotic languages). *Acta Linguistica Hafniensia 22*, 5–26.

Andersen, T. (1993). Vowel quality alternation in Dinka verb inflection. *Phonology 10*, 1–42.

Andersen, T. (1995). Morphological stratification in Dinka: On the alternations of voice quality, vowel length and tone in the morphology of transitive verbal rroot in a monosyllabic language. *Studies in African Linguistics 23*, 1–63.

Andersen, T. (1999). Vowel harmony and vowel alternation in Mayak (Western Nilotic). *Studies in African Linguistics 28*(1), 1–27.

Andersen, T. (2002). Case inflection and nominal head marking in Dinka. *JALL 23*, 1–30.

Andersen, T. (2014). Number in dinka. In A. Storch and G. J. Dimmendaal (Eds.), *Number – Constructions and Semantics. Case Studies from Africa, India, Amazonia & Oceania*, pp. 221–263. Amsterdam: John Benjamins.

Baerman, M, B. D. and G. Corbett (2009). Morphological Complexity: a typological perspective. In *European Science Foundation Exploratory Workshop on Words in Action*, Iistituto di Linguistica Computazionale, pp. 1–13.

Baerman, M. (2012). Paradigmatic chaos in Nuer. *Language 88*(3), 467–494.

Baerman, M. (2013). The diachronic puzzle of Nuer case inflection. In *Nilo-Saharan Linguistics Colloquium University of Cologne. May 22-24*.

Baerman, M., D. Brown, and G. G. Corbett (2017). *Morphological Complexity*. Cambdridge University Press.

Bates, D., M. Mächler, B. Bolker, and S. Walker (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software 67*(1), 1–48.

Bent, T., A. R. Bradlow, and B. A. Wright (2006). The Influence of Linguistic Experience on the Cognitive Processing of Pitch in Speech and Nonspeech Sounds. *Journal of Experimental Psychology: Human Perception and Performance 32*(1), 97–103.

Bermúdez-Otero, R. (1999). *Constraint interaction in language change: quantity in English and Germanic*. Ph. D. thesis, University of Manchester.

Bermúdez-Otero, R. (2011). Cyclicity. In M. van Oostendorp, C. Ewen, E. Hume, and K. Rice (Eds.), *The Blackwell companion to phonology*. Malden: Wiley-Blackwell.

Bermúdez-Otero, R. (2012). The architecture of grammar and the division of labour in exponence. In J. Trommer (Ed.), *The morphology and phonology of exponence*, pp. 8–83. Oxford University Press.

Bermúdez-Otero, R. (2013). The stem-level syndrome. In *Paper presented to the UPenn Linguistics Department, Speaker Series, Philadelphia, 11 April 2013*.

Bermúdez-Otero, R. (2018). Stratal phonology. In S. Hannahs and A. R. K. Bosch (Eds.), *The Routledge handbook of phonological theory*. Abingdon: Routledge.

Boersma, P. and D. Weenink (2016). Praat, v. 6.0.2.1. Retrievable online at http://www.praat.org.

Borowsky, T. (1993). On the Word level. In S. Hargus and E. M. Kaisse (Eds.), *Studies in Lexical Phonology (Phonetics and Phonology 4)*, pp. 199–234. San Diego: Academic Press.

Bossong, G. (1991). Differential object marking in romance and beyond. In D. A. Kibbee and D. Wanner (Eds.), *New Analyses in Romance Linguistics*, pp. 143–170. Benjamins, Amsterdam/Philadelphia.

Bruce, G. (1977). Swedish word accents in sentence perspective. *Lund: Gleerup*.

Bruce, G. (1983). Acentuation and timing in Swedish. *Folia Linguistica 17*, 221–238.

Bruce, G. and E. Gårding (1978). A prosodic typology for Swedish dialects. In E. Gårding, G. Bruce, and R. Bannert (Eds.), *Nordic Prosody*, pp. 219–228. Department of Linguistics, Lund University.

Burnham, D., E. Francis, D. Webster, S. Luksaneeyanawin, Attapaiboon, F. C., Lacerda, and P. Keller (1996). Perception of lexical tone across languages: Evidence for a linguistic mode of processing. In H. T. Bunnell and W. Idsardi (Eds.), *Proceedings of the Fourth International Conference on Spoken Language Processing*, Volume 1, pp. 2514–2517. Wilmington, DE: Applied Science and Engineering Laboratories.

Catford, J. C. (1977). *Fundamental problems in phonetics*. Edinburgh University Press.

Chen, M. Y. (1996). Tonal geometry – a Chinese perspective. In H. CT.J. and L. Y.A. (Eds.), *New Horizons in Chinese Linguistics.*, Volume 36 of *Studies in Natural Language and Linguistic Theory*. Springer, Dordrecht.

Chen, M. Y. (2000). *Tone sandhi: patterns across Chinese dialects*, Volume 92 of *Cambridge Studies in Linguistics*. Cambridge: Cambridge University Press.

Chomsky, N. and M. Halle (1968). *The sound pattern of English*. New York: Harper & Row.

Cohen, A. and J. 't Hart (1967). On the anatomy of intonation. *Lingua 19*, 177–192.

Connell, B. (2002). The Perception of Lexical Tone in Mambila. *Language and Speech 43*(2), 163–182.

Crazzolara, J. P. (1933). *Outlines of a Nuer Grammar*. Vienna: Anthropos.

Creissels, D. (2006). The construct form of nouns in African languages: a typological approach. In *36th Colloquium on African Languages and Linguistics, Leiden University, August 28 - 30*.

D'Alessandro, R. and T. Scheer (2015). Modular PIC. *Linguistic Inquiry 46*(4), 593–624.

de Lacy, P. (2012). Morphophonological Polarity. In *The Morphology and Phonology of Exponence*, pp. 121–159. Oxford University Press.

DiCanio, C. T. (2012). Cross-linguistic perception of Itunyosos Trique tone. *Journal of Phonetics 40*, 672–688.

Dimmendaal, G. J. (2000). Number marking and noun categorization in Nilo-Saharan languages. *Anthropological Linguistics 42*, 214–261.

D'Imperio, M. (2000). *The role of perception in defining tonal targets and their alignment*. Ph. D. thesis, The Ohio State University.

D'Imperio, M. and D. House (1997). Perception of questions and statements in Neapolitan Italian. In *Proceedings of Eurospeech 97, 5th European Conference on Speech Communication and Technology*, Rhodes, Greece, pp. 251–254.

Dixon, R. M. W. (2010). *Basic linguistic theory – volume 2 grammatical topics*. Oxford University Press.

Drachman, G., R. Kager, and A. Malikouti-Drachman (1995). Greek Allomorphy: an Optimality Account. In M. Dimitrova-Vulchanova and L. Hellan (Eds.), *Papers from the First Conference on Formal Approaches to South Slavic Languages*, Number 28 in University of Trondheim Working Papers in Linguistics, pp. 345–361.

Embick, D. (2014). Phase cycles, ϕ-cycles, and phonological (in)activity. In S. Bendjaballah, N. Faust, M. Lahrouchi, and N. Lampitelli (Eds.), *The form of structure, the structure of forms: essays in honor of Jean Lowenstamm*, pp. 271–286. Amsterdam: John Benjamins.

Ewan, W. G. and R. Krones (1974). Measuring larynx movement using the thyroumbrometer. *Journal of Phonetics 2*, 327–335.

Farkas, D. (1978). Direct and indirect object reduplication in Romanian. In *Papers from the fourteenth regional meeting of the Chicago Linguistic Society*, pp. 88–97. Chicago: Chicago Linguistic Society.

Faust, N. (2017). How low can you go? A note on vowel mutation in Nuer. *Journal of African Languages and Linguistics 38*(1), 51–64.

Faust, N. and E. Grossman (2015). Nuer (Western Nilotic): A preliminary survey.

Flanagan, J. L. and M. G. Saslow (1958). Pitch Discrimination for Synthetic Vowels. *Journal of the Acoustical Society of America 30*, 435–442.

Francis, A. L. and V. Ciocca (2003). Stimulus presentation order and the perception of lexical tones in Cantonese. *Journal of the Acoustical Society of America 114*, 1611–1621.

Francis, A. L., V. Ciocca, N. King Yu Wong, W. Ho Yin Leung, and P. Cheuk YanChu (2006). Extrinsic context affects perceptual normalization of lexical tone. *Journal of Acoustical Society of America 119*(3), 1712–1726.

Franich, K. (2016). Perception of Tonal Contours in Medʉmba. In *Proceedings of the 5th International Symposium on Tonal Aspects of Languages*.

Frank, J. W. (1999). Nuer noun morphology. Master's thesis, University of New York at Buffalo.

Gandour, J. and R. Harshman (1978). Cross-language differences in tone perception. *Language and Speech 21*(1), 1–33.

Gårding, E. and L. Eriksson (1991). On the perception of prosodic phrase patterns. In *Working Papers, Department of Linguistics*, Volume 38 of *Lund University*, pp. 45–70.

Gårding, E., P. Kratochvil, J.-O. Svantesson, and J. Zhang (1986). Tone 4 and tone 3 discrimination in modern standard Chinese. *Language and Speech 29*(3), 281–293.

Giuliano, R. J., P. Q. Pfordresher, E. M. Stanely, S. Narayana, and N. Y. Y. Wicha (2011). Native experience with a tone language enchances pitch discrimination and the timing of neural responses to pitch change. *Frontiers in psychology 2*(146).

Goldsmith, J. (1976). *Autosegmental Phonology*. Ph. D. thesis, Cambridge MA: MIT.

Gordon, M. and P. Ladefoged (2001). Phonation types: a cross-linguistic overview. *Journal of Phonetics 29*, 383–406.

Herrera Zendejas, E. (2000). Amuzgo and Zapotec: Two more cases of laryngeally complex languages. *Anthropological Linguistics 42*(4), 545–563.

Hombert, J.-M., J. J. Ohala, and W. G. Ewan (1979). Phonetic explanations for the development of tone. *Language 55*, 37–58.

House, D. (1990). *Tonal perception in speech*. Lund, Sweden: Lund University Press.

House, D. (1996). Differential perception of tonal contours through the syllable. In *ICSLP 96, Fourth International Conference on Spoken Language Processing. Philadelphia, PA, USA*, pp. 2048–2051.

House, D. (2004). Pitch and alignment in the perception of tone and intonation: pragmatic signals and biological codes. In *International Symposium on Tonal Aspects of Languages: Emphasis on Tone Languages*, pp. 93–96.

House, D. and J.-O. Svantesson (1996). Tonal timing and vowel onset characteristics in Thai. In *Proc. Pan-Asiatic Linguistics, 4th International Symposium, Bangkok*, pp. 104–113.

Hyman, L. (1993). Register tone and tonal geometry. In H. van der Hulst and K. Snider (Eds.), *The phonology of tone: the representation of tonal register*, pp. 75–108. Berlin, Mounton de Gruyter.

Hyman, L. (2006). Word-prosodic typology. *Phonology 23*, 225–257.

Itô, J. (1986). *Syllable theory in prosodic phonology*. Ph. D. thesis, Amherst: Unversity of Massachusetts.

Itô, J., A. Mester, and J. Padgett (1995). Licensing and underspecification in optimality theory. *Linguistic Inquiry 26*, 571–614.

Jones, P. J. (2014). *Tonal interactions in Kinande: cyclicity, opacity and morphosyntactic structure*. Ph. D. thesis, MIT.

Jongmana, A., Z. Qin, J. Zhang, and J. A. Sereno (2017). Just noticeable differences for pitch direction, height, and slope for Mandarin and English listeners. *The Journal of the Acoustical Society of America 142*(2).

Kager, R. (1996). On affix allomorphy and syllable counting. In U. Kleinhenz (Ed.), *Interfaces in Phonology*, Volume 41 of *Studia Grammatica*. Berlin: Akademie Verlag.

Kager, R. (1999). *Optimality Theory*. Cambridge, Cambridge University Press.

Kelly, N. E. and R. Smiljanić (2017). Perception of the Lexical Accent Contrast in One Variety of East Norwegain. *Language and Speech*, 1–19.

Kiparsky, P. (1982a). From cyclic phonology to lexical phonology. In H. van der Hulst and H. Smith (Eds.), *The structure of phonological representations*, pp. 131–175. Dordrecht, Foris.

Kiparsky, P. (1982b). Lexical Morphology and Phonology. In I.-S. Yang (Ed.), *Linguistics in the morning calm: selected papers from SICOL-1981*, pp. 3–91. Seoul: Hanshin Publishing Company.

Kiparsky, P. (2000). Opacity and cyclicity. *The Linguistic Review 17*, 351–365.

Kiparsky, P. (2015). Stratal OT: A synopsis and FAQs. In Y. E. Hsiao and L.-H. Wee (Eds.), *Capturing phonological shades within and across languages*, pp. 2–44. Newcastle upon Tyne, UK: Cambridge Scholars Publishing.

Klatt, D. H. (1973). Discrimination of fundamental frequency contours in synthetic speech: implications for models of pitch perception. *Journal of the Acoustical Society of America 53*, 8–16.

Kohler, K. (1987). Categorical pitch perception. In *Proceedings of the Eleventh International Congress of Phonetic Sciences*, Volume 5 of *Tallinn*, pp. 331–333.

Köhler, O. (1949). Zum konsonantischen auslautwechsel im nuer. *Zeitschrift für Phonetik und allgemeine Sprachwissenschaft 3*, 282–288.

Kuang, J. (2012). Registers in tonal contrasts. *Proceedings of the Third International Symposium on Tonal Aspects of Languages*.

Ladd, D. R. (1984). Declination: A review and some hypotheses. *Phonology Yearbook 1*, 53–74.

Ladd, D. R., B. Remijsen, and C. A. Manyang (2009). On the distinction between regular and irregular inflectional morphology: Evidence from Dinka. *Language 85*(3), 659–670.

Leben, W. (1973). Suprasegmental Phonology. *PhD dissertation, MIT*.

Leben, W. (1978). The representation of tone. In V. Fromkin (Ed.), *Tone: A Linguistic Survey*, pp. 177–220. Academic Press, New York.

Lehiste, I. (1970). *Suprasegmentals*. Massachusetts: MIT Press.

Liberman, M. and J. Pierrehumbert (1984). Intonational invariance under changes in pitch range and length. In M. Aronoff and R. T. Oehrle (Eds.), *Language, sound, structure: Studies in phonology presented to Morris Halle by his teacher and students*, pp. 157–223. Cambridge, MA: MIT Press.

Lindau, M. (1986). Testing a model of intonation in a tone language. *Journal of the Acoustical Society of America 80*, 757–764.

McCarthy, J. (1986). OCP Effects: Gemination and Antigemination. *LI* (17), 207–264.

McCarthy, J. (2000). Faithfulness and prosodic circumscription. In J. Dekkers, F. van der Leeuw, and J. van de Weijer (Eds.), *Optimality Theory. Phonology, Syntax and Acquisition*, pp. 151–189. Oxford University Press.

McCarthy, J. and A. Prince (1993). Generalized Alignment. In G. Booij and J. van Marle (Eds.), *Yearbook of morphology*, pp. 79–153. Dordrecht: Kluwer.

McCarthy, J. and A. Prince (1995). Faithfulness and reduplicative identity. In J. Beckman, L. W. Dickey, and S. Urbanczyk (Eds.), *Papers in Optimality Theory. University of Massachusetts Occasional Papers*, Volume 18, pp. 249–384. Amherst, Mass: GLSA.

McCarthy, J. and A. Prince (1999). Faithfulness and identity in prosodic morphology. In R. Kager, H. van der Hulst, and W. Zonneveld (Eds.), *The Prosody Morphology Interface*, pp. 218–309.

McCarthy, J. (1979). *Formal problems in Semitic phonology and morphology*. Ph. D. thesis, Massachusetts Institute of Technology.

McCloy, D. R. (2016). *phonR: tools for phoneticians and phonologists*. R package version 1.0-7.

Mester, A. R. (1994). The quantitative trochee in Latin. *NLLT 12*, 1–61.

Mixdorff, H., M. M. Lehlohonolo Mohasi, and T. Niesler (2011). A study on the perception of tone and intonation in Sesotho. In *Proceedings of the 12th Interspeech*, pp. 3188–3191.

Mohanan, K. P. (1982). *Lexical Phonology*. Ph. D. thesis, MIT.

Mok, P. P.-K. and P. W.-Y. Wong (2010a). Perception of the merging tones in Hong Kong Cantonese: preliminary data on monosyllables. *Proceedings of Speech Prosody*.

Mok, P. P.-K. and P. W.-Y. Wong (2010b). Production of the merging tones in Hong Kong Cantonese: preliminary data on monosyllables. *Proceedings of Speech Prosody*.

Monich, I. (2017). Vowel Length in Nuer. In *Poceedings of AMP 2016*.

Monich, I. (Forthcoming). Interplay of vowel quantity, consonant mutation, and tone in Nuer.

Monich, I. and M. Baerman (2018). Stem modification in Nuer. In E. Clem, P. Jenks, and H. Sande (Eds.), *Theory and description in African Linguistics: Selected papers from ACAL 47 (Contemporary African Linguistics)*. Berlin: Language Science Press.

Myers, S. (1997). OCP Effects in Optimality Theory. *Natural Language and Linguistic Theory*.

Nespor, M. and I. Vogel (1986). *Prosodic Phonology*. Dordrecht, Foris.

Nespor, M. and I. Vogel (1986 (REP 2007)). *Prosodic phonology.* Berlin. Mounton de Gruyter.

Newell, H. (2008). *Aspects of the morphology and phonology of phases*. Ph. D. thesis, McGill University.

Nolan, F. (2003). Intonational equivalence: an experimental evaluation of pitch scales. In *The 15th International Congress of Phonetic Sciences. Barcelona*, pp. 771–4.

Nyang, J. K. (2013). Eastern Jikäŋ̂ Nuer Verb Morphology. Master's thesis, Addis Abeba University.

Odden, D. (1996). *The phonology and morphology of Kimatuumbi*. Oxford: Clarendon Press.

Ohala, J. J. (1978). Production of tone. In V. A. Fromkin (Ed.), *Tone: A linguistic survey*, pp. 5–40. New York: Academic Press.

Ohde, R. N. (1984). Fundamental frequency as an acoustic correlate of stop consonant voicing. *The Journal of the Acoustical Society of America 75*, 224–230.

Paschen, L. (2018). A phonological account of reduplication-specific mutation.

Pesetsky, D. (1977). Russian Morphology and Lexical Theory. Unpublished Ms., MIT.

Pfordresher, P. Q. and S. Brown (2009). Enhanced production and perception of musical pitch in tone language speakers. *Attention, Perception and Psychophysics 71*, 1385–98.

Pierrehumbert, J. and S. Steele (1989). Categories of tonal alignment in English. *Phonetica 46*, 181–196.

Pinker, S. (1998). Words and rules. *Lingua 106*, 219–242.

Pinker, S. and A. Prince (1988). On language and connectionism: Analysis of a Parallel Distributed Processing model of language acquisition. *Cognition 28*, 73–193.

Prince, A. and P. Smolensky (1993/2004). *Optimality Theory: Constraint interaction in generative grammar*. Malden, MA and Oxford: Blackwell. Revision of 1993 Technical Report TR-2, Rutgers Center for Cognitive Science, Rudgers University, New Brunswick, NJ.

Pulleyblank, D. (1986). *Tone in Lexical Phonology*. Dordrecht: D. Reidel.

Quené, H. (2014). hqmisc: Miscellaneous convenience functions and dataset. R package version 1.1-6. https://cran.r-project.org/web/packages/hqmisc/index.html.

R Core Team (2014). *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing.

Reid, T. (2010). Aspects of phonetics, phonology and morphophonology of Thok Reel. MA thesis, University of Edinburgh.

Reid, T. (2019). *Aspects of phonetics, phonology and morphophonology of Nuer*. Ph. D. thesis, University of Surrey.

Remijsen, B. (2013a). *f0_plotnormtraces*. http://www.lel.ed.ac.uk/~bert/praatscripts.html.

Remijsen, B. (2013b). *f0_trim&check*. http://www.lel.ed.ac.uk/~bert/praatscripts.html.

Remijsen, B. (2013c). Tonal alignment is contrastive in falling contours in Dinka. *Linguistic Society of America 89*(2), 297–327.

Remijsen, B. and O. G. Ayoker (2014). Contrastive tonal alignment in falling contours in Shilluk. *Phonology 31*, 435–462.

Remijsen, B., O. G. Ayoker, and S. J. rgensen (2018). Three-level vowel length in Shilluk.

Remijsen, B. and L. Gilley (2008). Why are three-level vowel length systems rare? insights from dinka (luanyjang dialect). *Journal of Phnoetics 36*, 318–344.

Remijsen, B. and D. R. Ladd (2008). The tone system of the Luanyjang dialect of Dinka. *Journal of African Languages and Linguistics 29*(2), 173–213.

Remijsen, B., C. Miller-Naudé, and L. Gilley (2016). The morphology of shilluk transitive verbs. *Journal of African Languages and Linguistics 37(2)*, 201–245.

Rietveld, A. C. M. and C. Gussenhoven (1985). On the relation between pitch excursion size and prominence. *Journal of Phonetics 13*, 299–308.

Scheer, T. (2004). *A lateral theory of phonology*. Berlin, Boston: De Gruyter Mouton.

Selkirk, E. (1984). Phonology and syntax. The relation between sound and structure. *MITPress, Cambridge, Massachusetts*.

Selkirk, E. (1995). The prosodic structure of function words. In J. Beckman, L. W. Dickey, and S. Urbanczyk (Eds.), *Papers in Optimality Theory*, pp. 439–470. Amherst MA: GLSA Publications.

Shen, X. S. and M. Lin (1991). A perceptual study of Mandarin Tones 2 and 3. *Language and Speech 34*, 145–156.

Silverman, D. (1994). A case study in acoustic transparency: [spread] glottis and tone in Chinantec. In M. Gonzàlez (Ed.), *NELS 24: Proceedings of the 24th Annual Meeting of the North East Linguistic Society*, Volume 2, Amherst, MA, pp. 559–572. GLSA Publications.

Silverman, D. (2003). Pitch Discrimination During Breathy Versus Modal Phonation. In J. Local, R. Ogden, and R. Temple (Eds.), *Laboratory Phonology VI*, pp. 293–304. Cambridge University Press.

Simons, G. F. and C. D. Fennig (2018). *Ethnologue: Languages of the World* (21st ed.). Dallas, Texas: SIL International.

Snider, K. L. (1999). *The geometry and features of tone*. Dalls: SIL and University of Texas, Arlington.

Steriade, D. (1982). *Greek prosodies and the nature of syllabification*. Ph. D. thesis, Massachusetts Institute of Technology.

Stevens, K. N. (1998). *Acoustic phonetics*. Cambridge: MA: MIT Press.

Stewart, J. M. (1983). Downstep and floating Low Tones in Adioukrou. *Journal of African Languages and Linguistics 5*, 57–78.

Stewart, J. M. (1993). Dschang and Ebrie as Akan–type total downstep languages. In H. van der Hulst and K. Snider (Eds.), *The Phonology of Tone – the representation of tonal register*, pp. 185–244. Berlin: Mouton de Gruyter.

Storch, A. (2005). *The noun morphology of West Nilotic*. Köln: Rüdiger Köppe Verlag.

Sudhoff, S., D. Lenertova, R. Meyer, S. Pappert, P. Augurzky, I. Mleinek, N. Richter, and J. SchlieSSer (2012). *Methods in Empirical Prosody Research*. Berlin, Boston: De Gruyter.

't Hart, J. (1981). Differential sensitivity to pitch distance, particularly in speech. *The Journal of the Acoustical Society of America 69*(3).

't Hart, J., R. Collier, and A. Cohen (1990). *A Perceptual Study of Intonation – An Experimental-phonetic Approach to Speech Melody*. Cambridge: Cambridge University Press.

Trommer, J. (2011). *Phonological aspects of Western Nilotic mutation Morphology*. Habilitationsschrift, Institut für Linguistik, Universität Leipzig.

Trommer, J. and E. Zimmermann (2014). Generalised mora affixation and quantity-manipulating morphology. *Phonology 31*, 463–510.

Truckenbrodt, H. (1995). *Phonological phrases: their relation to syntax, focus and prominence*. Ph. D. thesis, MIT.

Tumtavitikul, A. (1995). Tonal movements in Thai. In *ICPhS 95. Stockholm*, pp. 118–121.

Turk, A., S. Nakai, and M. Sugahara (2006). Acoustic Segment DDuration in Prosodic Research: A Practical Guide. In S. Sudhoff, D. Lenertova, R. Meyer, S. Pappert, P. Augurzky, I. Mleinek, N. Richter, and J. Schlieğer (Eds.), *Methods in Empirical Prosody Research*, pp. 1–28. Berlin, Boston: De Gruyter.

Vaissère, J. (1971). *Contribution à synthèse par regles du francaisń*. Ph. D. thesis, Université des Langues et Lettres de Grenoble.

Vaissière, J. (1983). Language-independent prosodic features. In A. Cutler and D. Ladd (Eds.), *Prosody: Models and Measurements*, pp. 53–66. Springer Verlag.

van Oostendorp, M. (2005). Expressing inflection tonally. *Catalan journal of linguistics 4(1)*, 107–127.

Verhoeven, J. (1994). The discrimination of pitch movement in Dutch. *Journal of Phonetics 22*, 65–85.

Whalen, D. H. and A. G. Levitt (1995). The universality of intrinsic F0 of vowels. In *Journal of Phonetics*, Volume 23, pp. 349–66.

Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York.

Wolf, M. (2007). For an autosegmental theory of mutation. In L. Bateman, M. O'Keefe, E. Reilly, and A. Werle (Eds.), *University of Massachusetts Occasional Papers in Linguistics 32: Papers in Optimality Theory III*, pp. 315–404. Amherst MA: GLSA.

Wong, P. C. M. and R. L. Diehl (2003). Perceptual normalization for inter- and intratalker variation in cantonese level tones. *Journal of Speech and Hearing Research 46*, 413–421.

Xu, Y. (1998). Consistency of Tone-Syllable Alignment across Different Syllable Structures and Speaking Rates. *Phonetica 55*, 179–203.

Xu, Y. (1999). Effects of tone and focus on the formation and alignment of f_0 contours. *JPh* (27), 55–105.

Xu, Y. (2002). Articulatory constraint and tonal alignment. In B. B. and M. I. (Eds.), *Proceedings of the Speech Prosody 2002 Conference*, Aix-en-Provance, France, pp. 91–100.

Xu, Y. and X. Sun. (2002). Maximum speed of pitch change and how it may relate to speech. *Journal of the Acoustical Society of America 111*, 1399–1413.

Yigezu, M. (1995). The Nuer vowel system. *Journal of African languages*.

Yip, M. (1989). Contour tones. *Phonology 6*, 149–174.

Yip, M. (1990). *The Tonal Phonology of Chinese*. Ph. D. thesis, MIT. New York: Garland Publishing.

Yip, M. (1995). Tone in East Asian languages. In J. Goldsmith (Ed.), *Handbook of Phonological Theory*, pp. 476–94. Oxford: Basil Blackwell.

Yip, M. (2002). *Tone*. Cambridge: Cambridge University Press.

Zhang, J. (2002). *The effects of Duration and sonority on contour tone distribution – A typological survey and formal Analysis*. New York: Routledge.

Zimmermann, E. (2015). Allomorphy between tone and segments. In *Proceedings of NELS 45, GLSA Publications, Amherst*.

Zimmermann, E. (2016). Allomorphy between tone and segments: An autosegmental account of Yucunany Mixtepec Mixtec. In *NELS 45*.

Zimmermann, E. (2018). Being Exceptional is Being Weak: Tonal Exceptions in San Miguel el Grande Mixtec. In *Proceedings of AMP*.

Zsiga, E. and R. Nitisaroj (2007). Tone features, tone perception, and peak alignment in Thai. *Language and Speech 50*, 343–383.

Appendix A

List of inflected nouns

Table A.1: **Inflection of loanwords**

STEM TYPE	NOM SG	OBL SG	NOM PL	OBL PL	gloss
STABLE	ɟè̤k	ɟè̤k-é̤	ɟè̤k-ní̤	ɟè̤k-ní̤	**‘jug’**
	gálàm	gálàm-é̤	gáˑlàm-ní	gálàm-ní̤	**‘pen’**
	bè̤nt̪è̤lɔ́ˑn	bè̤nt̪è̤lɔ̀ˑn-é̤	bè̤nt̪è̤lɔ̀ˑn-ní̤	bè̤nt̪è̤lɔ̀ˑn-ní̤	**‘pants’**
	gà̤míˑt̪	gà̤mìˑt̪-ké̤	gà̤mìˑt̪-ní	gà̤mìˑt̪-ní̤	**‘shirt’**
	t̪úrɛ̀	t̪úrɛ̀-ké̤	t̪úrɛ̀-ní̤	t̪úrɛ̀-ní̤	**‘picture’**
	cúrâˑb	cúràˑb-é̤	cúràˑb-ní	cúràˑb-ní̤	**‘socks’**
	tá̤rɛ̀	tá̤rɛ̀-ká̤	tá̤rɛ̀-ní̤	tá̤rɛ̀-ní̤	**‘head scarf’**
	càkîˑn	càkìˑn-ké̤	càkìˑn-í	càkìˑn-í̤	**‘knife’**
	cìaːl	cíaːl-ké̤	cíaːl-í	cíaːl-í̤	**‘scarf’**
	kʊ́ˑt	kó̤ˑt-kè̤	kʊ̀ˑt-ní̤	kʊ̀ˑt-ní̤	**‘coat’**
	pé̤c	pé̤j-kè̤	pè̤c-ní̤	pè̤c-ní̤	**‘page’**
	bôk	bòk	bōk-ní̤	bōk-ní̤	**‘book’**

Table A.2: **Inflection of native words**

CLASS	NOM SG	OBL SG	NOM PL	OBL PL	gloss
STABLE	kè̤ːr	kè̤ˑr-é̤	kè̤ˑr-í̤	kè̤ˑr-í̤	**‘line’**
	t̪âːk	thâːk-è̤	t̪àːk-ní̤	t̪àːk-ní̤	**‘clock’**
	bâˑp	bâˑb-è̤	bàˑb-ní̤	bàˑb-ní̤	**‘door’**
	dɛ̂ˑp	dɛ̂ˑp-kè̤	dɛ̄ˑp-ní̤	dɛ̄ˑp-ní̤	**‘butter’**
	nè̤ˑn	nè̤ˑn-ké̤	nè̤ˑn-í̤	nè̤ˑn-í̤	**‘mirror’**
	dêˑc	dêˑj-kè̤	dèˑj-ní̤	dèˑj-ní̤	**‘soldier’**
	twɔ̤̄ˑt	twɔ̤̄ˑt-ké̤	twɔ̤̄ˑt-ní̤	twɔ̤̄ˑt-ní̤	**‘wild goose’**
	gwàk	gwàk-é̤	gwàk-ní̤	gwàk-ní̤	**‘fox’**
	pâˑl	pâˑl-kè̤	pàˑl-í̤	pàˑl-í̤	**‘ritual’**
	gwák	gwàk-é̤	gwák-ní̤	gwàk-ní̤	**‘dry grass’**
	gá̤ˑc	gá̤ˑj-kè̤	gà̤ˑj-ní̤	gà̤ˑj-ní̤	**‘belt’**
	kôˑt̪	kôˑt̪-kè̤	kòˑt̪-ní̤	kòˑt̪-ní̤	**‘cup’**
	wàt	wàt-é̤	wàt-ní̤	wàt-ní̤	**‘relative’**
	kɔ̂m	kɔ̀m-é̤	kɔ̀m-ní̤	kɔ̀m-ní̤	**‘chair’**
	tɛ̂ːr	tɛ̂ːr-è̤	tɛ̀ːr-í̤	tɛ̀ːr-í̤	**‘September’**
	bṳ́ˑk	bṳ́ɔ̤ːk	bṳ̀ɔ̤ːŋ-í̤	bṳ̀ɔ̤ːŋ-í̤	**‘Nuer god’**
	gɔ̂ːk	gɔ̀aˑk	gɔ̄aˑk-ní̤	gɔ̄aˑk-ní̤	**‘monkey’**
	tɛ̂r	tɛ̂ˑr	tɛ̄ˑr-í̤	tɛ̄ˑr-í̤	**‘conflict’**
	tɔ̤̀t	tɔ̤̀a̤t	tɔ̤̀t-ní̤	tɔ̤̀t-ní̤	**‘summer’**

CLASS	NOM SG	OBL SG	NOM PL	OBL PL	gloss
	(mass noun)		ná̤k	ná̤k-nì̤	**‘yogurt drink’**
	wɔ̤́ˑk	wṳ́ˑk-ɐ̤̀	wɔ̤́ːk	wɔ̤́ːk-nì̤	**‘shoulder’**
	rɛ̀ɐ̤ːt̪	rɛ̀ˑt̪-kɐ̤́	rɛ̤́ˑt̪	rɛ̤́ˑd̪-nì̤	**‘dryness’**
	tɔ̂ˑk	tôˑk-ɐ̤̀	tôːk	tôːk-nì̤	**‘gourd’**
	tét	tét-kɐ̤̀	tét	tét-nì̤	**‘hand’**
	kɔ̤́a̤ːk	kɔ̤́ˑk-ɐ̤̀	kɔ̤́a̤k	kɔ̤́a̤k-nì̤	**‘hole’**
	nʊ̄p	nʊ̄p-ɐ̤́	nʊ̂ˑp	nʊ̂ˑp-nì̤	**‘message’**
HYBRID	cɔ̤̀a̤ː	cɔ̤̀ː-kɐ̤́	cɔ̤̄ˑw	cɔ̤̄ˑw-ní̤	**‘bone’**
	lɔ̤́ːr	lṳ́ˑr-ɐ̤̀	lɔ̤́ˑr	lɔ̤́ːr-ì̤	**‘Acacia Seyal tree’**
	ɟá̤ˑl	ɟá̤ˑl-ɐ̤́	ɟà̤ːl	ɟá̤ːl-í̤	**‘visitor’**
	rí̤e̤ˑt	rí̤ˑt-kɐ̤̀	rí̤e̤ːt	rí̤e̤ːt-nì̤	**‘word’**
	lɐ̤̀k	lɐ̤̀k-ɐ̤́	lá̤ːk	lá̤ːk-nì̤	**‘dream’**
	wɐ̤́ːt̪	wɐ̤́ːt̪-kɐ̀	wɐ̤̀t̪	wɐ̤̀t̪-ní̤	**‘warrior’**
	rɔ̀aːm	rɔ̀ːm-kɐ̤́	rɔ̂ːm	rɔ̂ːm-nì̤	**‘sheep’**
	kè̤ˑn	kè̤ˑn-ɐ̤́	ké̤ˑn	ké̤ˑn-nì̤	**‘type of bird’**
	dó̤ːr	dò̤ːr	dʊ̂ˑr	dʊ̂ˑr-ì̤	**‘tribe’**
	ɟó̤m	ɟò̤m	ɟò̤m	ɟó̤m-nì̤	**‘jaw’**
UNSTABLE	bṳ́ˑl	bṳ̀ɔ̤ːl	bṳ́ɔ̤ˑl	bṳ́ɔ̤ˑl-ì̤	**‘drum’**
	rɔ̤́ˑt̪	rɔ̤̀a̤ːt̪	rɔ̤́a̤ːt̪	rɔ̤́a̤ːt̪-nì̤	**‘armpit’**
	d̪ó̤ːl	d̪ʊ̀l	d̪ɔ̂ːl	d̪ɔ̄ːl-í̤	**‘boy’**
	kêːr	kè̤r	ké̤r	ké̤r-ì̤	**‘calabash plant’**

STEM TYPE	NOM SG	OBL SG	NOM PL	OBL PL	gloss
UNSTABLE (cont.)	kôt̪	kòt̪	kṳ́t̪	kṳ́t̪-nì̤	**‘god’**
	lɔ̂ˑc	lɔ̀aːc	ló̤ˑc	ló̤ˑc-nì̤	**‘heart’**
	lòɲ	lùɔˑɲ	lûɔˑɲ	lúɔˑɲ-nì̤	**‘lion’**
	gɔ̂ˑl	gɔ̀aːl	gɔ̂al	gɔ̂al-ì̤	**‘smoke fire’**
	kâl	kàl	kɘ̤́ˑl	kɘ̤́ˑl-ì̤	**‘fence’**
	bâˑr	bàːr	bâr	bâr-ì̤	**‘lake’**
	câˑk	cà̤ːk	cɘ̤́ˑk	cɘ̤́ˑk-nì̤	**‘milk’**
	dîˑt	dìɛːt	dîːt	dîˑt-nì̤	**‘bird’**
	jé̤ˑr	jè̤ːr	jé̤r	jé̤r-ì̤	**‘river’**
	lwâˑk	lwàːk	lwé̤ːk	lwé̤ːk-nì̤	**‘cattle hut’**
	mún	mṳ̀ɔ̤ːn	mɔ́n	mɔ́n-ì̤	**‘soil’**
	rṳ́p	rṳ́ɔ̤ːp	rɔ̤́p	rɔ̤́p-nì̤	**‘forest’**
	rí̤ɛ̤ˑl	rì̤a̤ːl	rí̤ɛ̤ːl	rí̤ɛ̤ːl-ì̤	**‘type of fish’**
	wàŋ	wàŋ	wɘ̤́ˑŋ	wɘ̤́ˑŋ-nì̤	**‘eye’**
	rwɛ̤́ˑl	rwèːl	rwél	rwél-ì̤	**‘spring’**
	wɘ̤́ˑn	wà̤ˑn	wá̤ˑn	wá̤ˑn-ì̤	**‘thief’**
	wé̤c	wé̤c	wíː	wíː-nì̤	**‘village’**
	pàˑj	pà̤t̪	pɘ̤́ˑt̪	pɘ̤́ˑt̪-nì̤	**‘moon’**
	lâp	làːp	lɘ̤́p	lɘ̤́p-nì̤	**‘placenta’**
	ɟɔ̀k	ɟàk	ɟóˑk	ɟóˑk-nì̤	**‘back’**
	dɛ̂ˑl	dɛ̀ɘ̤ːl	dé̤t	dé̤ːt	**‘sheep/goat’**
	ràːn	ràn	nâːt̪	↓nât̪	**‘person/Nuer’**
	jâŋ	jàːŋ	hɔ́ˑk	hɔ̤̀ːk	**‘cow’**
	cí̤e̤k	cì̤k	mɘ̤̀ˑn	mɘ̤́ːn	**‘woman’**
	kwɛ̤́n	kwà̤ˑn	kwàn	kwâˑn	**‘food’**
	ɟàˑt̪	ɟàˑt̪	ɟɛ́ˑn	ɟɛ̂ˑn	**‘tree’**
	gàt	gàt-kɘ̤́	gâːt	gàːn	**‘child’**

Appendix B

Additional pitch tracks

(364) *M_L*

a. cì-kɔ̄n là·ŋ **nɛ̂·n**
PVF-3PL mosquito.net see
'We have seen the mosquito net .' L-toned noun

b. cì-kɔ̄n wá̤·n nɛ̀·n
PVF-3PL thief\PL see
'We have seen thieves.' H-toned noun

c. cì-kɔ̄n lā̤·m **nɛ̂·n**
PVF-3PL k.fish see
'We have seen a kind of fish.' mid-toned noun

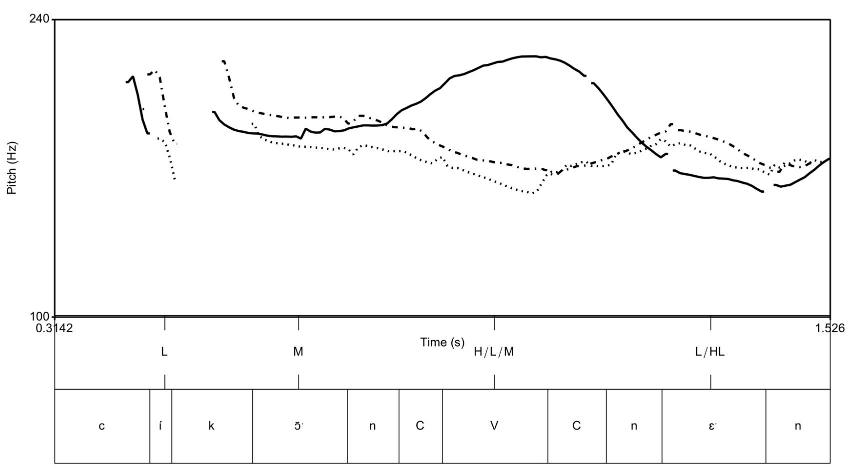


Figure B.1: F_0 tracks showing H tone epenthesis in two of the three sentences of (364) (*M_L*, perfective) pronounced by a female speaker. The verbal stem follows one H-toned (solid line), one L-toned (dotted line), and one mid-toned (dashed line) noun.

(365) *HL_HL*

a. cí-kɔ̂n làˑŋ **nɛ̂ˑn**
NEG-3PL\NEG mosquito.net see\NEG
'We are not seeing the mosquito net.' L-toned noun

b. cí-kɔ̂n wá̤ˑn **nɛ̂ˑn**
NEG-3PL\NEG thief\PL see\NEG
'We are not seeing thieves.' H-toned noun

c. cí-kɔ̂n lā̤ˑm **nɛ̂ˑn**
NEG-3PL\NEG k.fish see\NEG
'We are not seeing kind of fish.' mid-toned noun

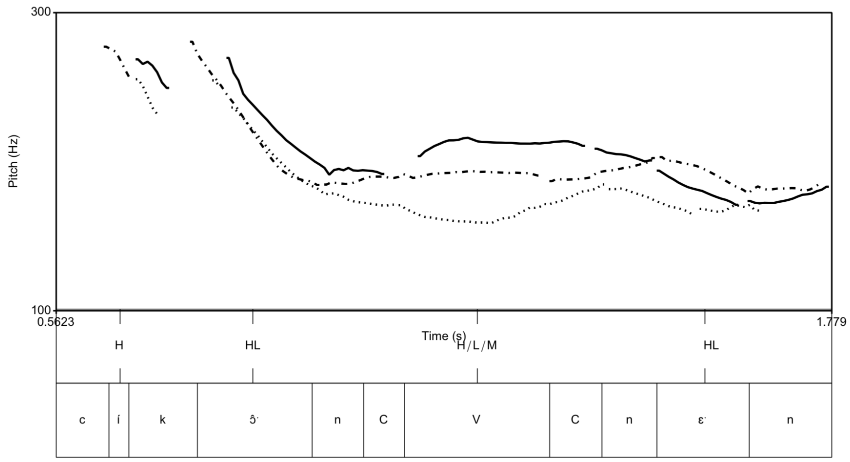


Figure B.2: F_0 tracks showing grammatical HL tone on verbal stem in the three sentences of (365) (*HL_HL*, negative present) pronounced by a female speaker. The verbal stem follows one H-toned (solid line), one L-toned (dotted line), and one mid-toned (dashed line) noun.

Selbstständigkeitserklärung

und Erklärung über frühere Promotionsversuche

Hiermit versichere ich, dass ich die vorliegende Arbeit ohne unzulässige Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe; die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sind als solche kenntlich gemacht.

Ich habe nicht die Hilfe eines Promotionsberaters/einer Promotionsberaterin in Anspruch genommen. Die Arbeit wurde zuvor weder im Inland noch im Ausland in gleicher oder ähnlicher Form einer anderen Institution vorgelegt. Sie ist weder Bestandteil eines ruhenden Verfahrens noch wurde sie in einem gleichartigen Promotionsverfahren als endgültig nicht bestanden erklärt. Die Arbeit ist vorher auch noch nicht veröffentlicht worden.

Ich erkläre, dass ich bisher noch keine Promotionsversuche unternommen habe.

Leipzig, 22/05/2019

Siri Moen Gjersøe