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ARTICLE

Nuer has a floating suprasegmental component consisting of quantity and tone

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Abstract

It is well-attested that floating tones can associate across a word boundary, but it is typologically unusual for floating weight units to do so. The Nuer language presents a floating suprasegmental component (FSC), which is part of lexical morphemes, and includes a unit of quantity and a High tone. This component is located at the left edge of nouns and is realised primarily across a word boundary on a preceding vowel. This article examines the FSC through a phonological analysis and a production study with eight speakers. These investigations reveal how the FSC interacts with the specifications for vowel length and tone of the adjacent context. Specifically, the weight unit of the FSC lengthens a preceding word-final short vowel, and its High tone combines in a compositional manner with tone of this preceding context. Comparisons with related languages suggest that the FSC developed out of a word-initial vowel /a/.

Contents

1. Introduction

1.1. Motivation

Tone and vowel length require segmental material for their phonetic realisation. However, this does not preclude the possibility of their being unattached or 'floating' in the phonological representation of a

morpheme. In this scenario, for the suprasegmental feature to surface, it needs to get associated with a suitable docking site, provided by an adjacent constituent.

In relation to tone, the property of being floating can be defined as lacking association with a tone-bearing unit. Floating tones are found in many tone systems, and the phenomenon has been a key consideration in the development of autosegmental theory (cf. Welmers 1970; Goldsmith 1976; Kenstowicz 1994). There are many languages in which floating tones are part of the underlying specification of a morpheme, and the docking site can be located across a word boundary (e.g., McKendry 2013 on South-eastern Nochixtlán Mixtec). When it comes to weight units or moras, the property of being floating implies prosodic defectiveness in the sense of Zimmerman (2017: 40–41), that is, a lack of integration with higher and lower prosodic constituency structure. There are many reports of moraic affixes, that is, weight units that integrate with a stem (Trommer 2015; Zimmerman 2017). By contrast, the case for floating weight units that associate across a word boundary is very limited: to date, detailed evidence for this configuration is reported only for Shilluk, a West Nilotic language spoken in South Sudan (Remijsen & Ayoker 2020). Floating quantity in Shilluk conditions an increase in duration of over 40% on the vocalic prefix of a following word, but is not realised in the absence of this particular context. Remijsen & Ayoker (2020) represent it as a floating mora at the right edge of the word.

In this article, we report another instance of floating quantity that associates across a word boundary. It is located at the left edge of words that have it. It is found in Nuer, which is another West Nilotic language. We illustrate the phenomenon in (1) using the words [gàt] 'child' and [dɔ̀k] 'Dok person'.[1,2,3,4] As shown in (1a) and (1b), in utterance-initial position both words are monosyllabic and Low-toned. But when they follow a word that ends in a short vowel, as in (1c) and (1d), the surface phonological realisation of this vowel differs. It has a shorter duration and a level low tone before [gàt] 'child' in (1c), and a longer duration and a rising tone before [dɔ̀k] 'Dok person' in (1d).

(1) a. [gàt] ►
/gàt/
child
'the child'

b. [dɔ̀k] ►
/$^{\mu}$dɔ̀k/
Dok.person
'the Dok person'

c. [ɯ̟ɻ̟́n cwɛ̂aadɻ̟̀ gàt] ►
/ɯ̟ɻ̟́n cwɛ́aat-ɻ̟̀ gàt/
PR.ISG kiss.teeth.at-ISG child
'I am kissing teeth at the child.'

[1]A Dok person is a member of the Leer clan of (Western) Nuer.

[2]The following notes relate to derivation of surface phonological forms that appear throughout the document: the High toneme has a falling realisation on modal vowels (Reid 2019; Monich 2020); stem-final plosives (C_2) have voiced realisation in context between sonorants (Reid 2019: 59–60). Dissimilatory lowering changes High tones to Low in certain environments. We have already applied dissimilatory lowering in the underlying representation within verb forms in these illustrations.

[3]Abbreviations and symbols used in this article: 1 = first person; AP = antipassive; C = consonant; F = the *F*-test; f0 = fundamental frequency; F1 = first formant; F2 = second formant; F3 = third formant; FIN = finite; FSC = floating suprasegmental constituent; H = High tone; IMPF = imperfective; L = Low tone; M = Mid tone; PL = plural; PR = pronoun; SG = singular; T = tone; V = vowel; σ = syllable node; μ = mora node; ($^{\mu}$) = floating constituent consisting of a mora and High tone; ɔ, ɔa = short vowel (V); ɔɔ, ɔaa = long vowel (VV); ɔɔɔ, ɔaaa = overlong vowel (VVV); á = High tone; à = Low tone; ā = Mid tone; [â] = falling contour tone; . = syllable boundary.

[4]The symbol ► beside an example is a link to an embedded audio recording that can be played in pdf readers that support this feature. The audio files are also available as Supplementary Material that can be downloaded separately.

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d. [ɯ̰n cwêaadə̰̀ə́ dɔ̀k] ▶
/ɯ̰n cwɛ́at-ə̰̀ ᵘ́dɔ̀k/
PR.1SG kiss.teeth.at-1SG Dok.person
'I am kissing teeth at the Dok person.'

The same process applies when words such as 'Dok person' occur in other environments involving a preceding open syllable with short vowels (e.g., the preposition *kɛ̀*). This suggests that the phenomenon is of a phonological rather than morphosyntactic nature. We propose that the differences in the suffix vowel before the two nouns in (1c) and (1d) can be accounted for by postulating that Nuer has a floating suprasegmental component (FSC). Because the vowel in (1d) differs in duration compared to (1c), we infer that this FSC includes quantity which we represent as the floating mora (ᵘ) in the UR representation in (1b) and (1d). The increase in duration of the vowel in the environments like (1d) is auditorily salient: the duration of the underlyingly short suffix vowels is comparable to that of the long vowels, all other things being equal. In addition, the FSC gives rise to a change in tone on the preceding vowel; this is also evident from comparing (1d) and (1c). Because the syllables on either side of the FSC are Low-toned in the surface phonology, the rising tone pattern on the suffix vowel in (1d) cannot be attributed to the effects of a tone target on one of these syllables. On the basis of the rising tone in (1d) we infer that the FSC itself includes a specification for High tone.

Situating the FSC within phonological theory and typology, floating affixes have been invoked in the analysis of stem-internal morphology (Akinlabi 1996; Trommer 2015; Zimmerman 2017; Rolle 2018). The FSC in Nuer is different in that it is not a grammatical morpheme but is instead part of the phonological specification of lexical morphemes. The goal of this article, then, is to present a descriptive analysis of the FSC in Nuer, and to confirm through a production study the auditory impressions that underlie it. We expect to find substantial differences in both vowel duration and fundamental frequency as a function of the FSC.

The article is structured as follows: after providing relevant background information on Nuer (§1.2), we present a phonological analysis of the FSC (§2). This analysis forms the basis for an acoustic study with eight speakers; §3 describes its methodology, and §4 its results. In §5, we address the question of the diachronic development of the FSC. The article is concluded in §6.

1.2. Nuer language background

Nuer (ISO 6393: nus / Glottocode: nuer1246) is a West Nilotic language of the Nilo-Saharan phylum (Nilo-Saharan, Eastern Sudanic, Nilotic, Western, Dinka-Nuer), spoken in the Republic of South Sudan and in the Gambella region of Ethiopia by approximately 1.7 million people (Eberhard *et al.* 2021). Within South Sudan, four dialect clusters can be distinguished: Western Nuer, Central Nuer, and two Eastern – Nasir Nuer and Lou Nuer (Reid 2021). Each of these four clusters consists of a number of dialects (Reid 2022b). The differences between the dialects relate to phonology, morphology, syntax and lexicon. This article reports on the Lou Nuer dialect cluster. It is spoken in the Republic of South Sudan, along the border with Ethiopia.

Lexical stems in Nuer are predominantly monosyllabic. The syllable shape of lexical stems is C_1(w/j)V(V)(V)(C_2). The onset can consist of a single consonant, or it may additionally include a semivowel; the vowel can be short (V), long (VV), or overlong (VVV); and the coda is optional.[5] The lexical stem can take a suffix, but there are no prefixes.[6]

The Lou Nuer consonant inventory consists of voiceless and voiced plosives and nasals at five places of articulation /p, b, m, t̪, d̪, n̪, t, d, n, c, ɟ, ɲ, k, g, ŋ/; the fricative phoneme /h/; the liquids /l, r/; and three

[5] In open syllables, vowel length is contrastive in a binary sense at most: /V/ *vs.* /VV/. These are found specifically in function words; the vowels in open syllables can be either short or long. In lexical stems that consist of an open syllable, vowel length is not contrastive at all, and the duration of these vowels is phonetically ambiguous between [VV] and [VVV]. In suffixes, vowel length is also not contrastive – they are underlyingly short (and subject to phonological lengthening due to FSC).

[6] In §5, we will return to the lack of prefixes in the synchronic morphophonology.

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approximants /w, j, ɰ/. Voicing in plosives is contrastive in stem-initial position (C_1) only. In stem-final position (C_2), plosives are voiced between sonorants and voiceless otherwise (Reid 2019: 58–60).

The Nuer vowel inventory consists of 22 phonemes, of which 14 are monophthongs /ɪ, i̱, e, e̱, ɛ, ʌ̱, a, a̱, ɔ, ɔ̱, o, o̱, ʊ, u̱/ and 8 are diphthongs /ɪɛ, i̱e̱, ɛa, e̱a̱, ɔa, ɔ̱a̱, ʊɔ, u̱ɔ̱/ (Reid 2019: 42–47; Reid 2024, n.d.). The vowel phonemes contrast in height, backness and voice quality (modal, e.g., /a/, *vs*. breathy, e.g., /a̱/).

Nuer vowels have a ternary length contrast (Monich 2017; Reid 2019: 48–51). Monophthongs and diphthongs alike can be short (e.g., /ɛ, ɛa/), long (e.g., /ɛɛ, ɛaa/) or overlong (e.g., /ɛɛɛ, ɛaaa/). In terms of phonological quantity, the diphthongs such as /ɛa, ɛaa, ɛaaa/ are equal to monophthongs such as /ɛ, ɛɛ, ɛɛɛ/, respectively.

Nuer is a tonal language. Lou Nuer has three tonemes: High, Mid and Low. The tonemes have a variety of surface realisations including a rise and a fall (Gjersøe 2019; Reid 2019: 132–140, Reid 2024; Monich 2020).

Suprasegmental and vocalic contrasts both play an important role in Nuer morphology (Crazzolara 1933; Storch 2005; Faust 2017; Baerman *et al.* 2019; Gjersøe 2019; Monich & Baerman 2019; Reid 2019; Baerman & Monich 2021).

2. Descriptive analysis of the floating suprasegmental component

The effects of the FSC were first observed by Crazzolara (1933: 24–25), and then corroborated by the perceptual reports in Reid (2019: 77–80, 2021, 2022b), Gjersøe (2019: 99–100), and Monich (2021). The FSC is also represented in the standard Nuer orthography (Reid 2022b), and speakers tend to be aware of the vowel lengthening associated with it. Previous studies differ with respect to the analysis of the FSC: Crazzolara (1933) and Reid (2019, 2021, 2022b) report changes in vowel length and tone, while Monich (2021) reports only vowel lengthening, and Gjersøe (2019) only tonal changes.

In this section, we present a systematic descriptive analysis of the FSC in the Lou Nuer dialect cluster. The current analysis was developed through elicitation sessions with a reference speaker and corroborated by spontaneous speech data (narrative analysis) and data from 12 additional speakers of Lou Nuer. Data collection for this study took place over video calls, between May 2020 and February 2022 (see also §3.3).

The FSC is located at the left edge of the noun, and, in certain contexts, affects the surface-phonological form of utterances containing these words. As a means of illustration, consider the realisation of two nouns: /gàt/ ‘child’, which does not have the FSC, and /ʱdɔ̀k/ ‘Dok person’, which does. They are presented in (2), and further illustrated by the embedded sound files. In (2a) and (2b), the nouns are uttered as a single-word utterance, just as in (1a) and (1b). The FSC does not surface here: both words are realised as monosyllables with a short vowel and a Low tone. In (2c) and (2d), they are preceded by a High-toned open syllable with a short vowel. These examples differ from the ones in (1c) and (1d), where the preceding vocalic suffix was Low-toned. It is in this environment – preceded by a vocalic suffix – that we find evidence for the difference in underlying specification. It is not manifested on the nouns themselves, but rather on the preceding context. Before the noun without the FSC in (2c), the preceding suffix has a short vowel; before the noun with the FSC in (2d), the preceding suffix has a long vowel.

(2) a. [gàt] ▶
/gàt/
‘child’

b. [dɔ̀k] ▶
/ʱdɔ̀k/
‘Dok person’

c. [ɰʌ́n ɟjābʌ́ gàt] ▶
/ɰʌ́n ɟjāp-ʌ́ gàt/
PR.ISG touch-ISG child
‘I am touching the child.’

d. [ɰʌ́n ɟjābʌ́ʌ̱ dɔ̀k] ▶
/ɰʌ́n ɟjāp-ʌ́ ʱdɔ̀k/
PR.ISG touch-ISG Dok.person
‘I am touching the Dok person.’

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We account for this by postulating that the FSC contains a floating mora that docks onto the preceding vocalic context, thereby inducing phonological lengthening of an underlyingly short vowel.

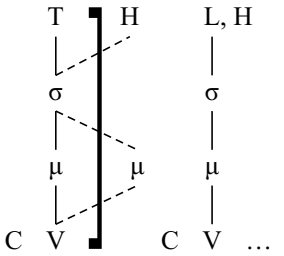
In the examples in (2c) and (2d), the tone on the preceding suffix is High underlyingly, and it remains High regardless of whether the following noun has the FSC or not. But in the examples containing the same nouns in (3), repeated from (1), the tone on the preceding suffix differs. This suffix has an underlying High tone which dissimilates to low following the High tone on the verb stem (Reid 2021). Before the noun without the FSC (3a), the suffix has low surface tone and before the noun with the FSC (3b), the suffix has a rising tone. The rising contour in (3b) is due to the FSC.[7] Note that the tone on the noun stem is not a factor contributing to the surface realisation of the suffix – both /gàt/ and /ᵘ́dɔ̀k/ carry a Low tone on the stem syllable. To account for the difference in tone on the suffix between examples (3a) and (3b) we postulate that, in addition to a floating mora, the FSC includes a floating High tone. The presence of this tone in the underlying representation is revealed in the context of a preceding open syllable and only when this syllable is Low-toned (3b). When the preceding open syllable is High-toned, as in (2d), the High tone of the FSC associates vacuously.

(3) a. [ɯ̀n cwêaadə̀ gàt] ▶
/ɯ̀n cwɛ́at-ə̀ gàt/
PR.ISG kiss.teeth.at-ISG child
'I am kissing teeth at the child.'

b. [ɯ̀n cwêaadə̀ə́ dɔ̀k] ▶
/ɯ̀n cwɛ́at-ə̀ ᵘ́dɔ̀k/
PR.ISG kiss.teeth.at-ISG Dok.person
'I am kissing teeth at the Dok person.'

A schematic representation of the FSC is provided in (4). The specification for tone on the stem syllable of the FSC noun as either L(ow) or H(igh) will be justified below. The FSC consists of a weight unit and a High tone, both of which associate leftward across the word boundary (represented by the closing square bracket).

(4)



The effects of the FSC on the preceding context are also found when a noun with the FSC has a High-toned stem. This can be seen from the examples in (5): (5a), (5c) and (5e) show a High-toned noun without the FSC, and examples (5b), (5d) and (5f) show a High-toned noun with the FSC. In each case, we present the nouns as a one-word utterance ((5a), (5b)), with the preceding suffix vowel being High-toned ((5c), (5d)), and with the preceding suffix vowel being Low-toned ((5e), (5f)). When the preceding suffix vowel is High-toned (5d), the FSC induces a long vowel. When the preceding suffix vowel is Low-toned (5f), the FSC gives rise to both a long vowel and a rising tone. Overall, the derivation of the surface realisations in the FSC words with High-toned stem syllables is accounted for by the schema in (4).

[7] The descriptive analysis of the melodic shape of the suffix vowel in (3b) as rising is informed by acoustic analysis (f0 traces). In our auditory impressions, the melodic shape is very similar to that of the High-toned realisations of the suffix in (2d).

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(5) a. [kǫ̣́m] ▶
/kǫ̣́m/
'insect'

b. [kų̣́m] ▶
/ᴹ́kų̣́m/
'hat'

c. [ɯą́n ʧjābą́ kǫ̣́m] ▶
/ɯą́n ʧjāp-ą́ kǫ̣́m/
PR.ISG touch-ISG insect
'I am touching the insect.'

d. [ɯą́n ʧjābą́ą̣ kų̣́m] ▶
/ɯą́n ʧjāp-ą́ ᴹ́kų̣́m/
PR.ISG touch-ISG hat
'I am touching the hat.'

e. [ɯą́n cwêaadą̀ kǫ̣́m] ▶
/ɯą́n cwéaat-ą̀ kǫ̣́m/
PR.ISG kiss.teeth.at-ISG insect
'I am kissing teeth at the insect.'

f. [ɯą́n cwêaadą̀ą́ kų̣́m] ▶
/ɯą́n cwéaat-ą̀ ᴹ́kų̣́m/
PR.ISG kiss.teeth.at-ISG hat
'I am kissing teeth at the hat.'

Nouns with the FSC that have Mid-toned stem syllables interact with the preceding context in a different manner: the FSC affects the quantity of the vowel in a preceding open syllable, but not the specification for tone. This is shown in (6), where a noun without the FSC and a noun with the FSC each appear as a one-word utterance ((6a), (6b)), with the preceding High-toned suffix ((6c), (6d)), and with the preceding Low-toned suffix ((6e), (6f)). Comparing (6c) and (6e) with (6d) and (6f), we see that the FSC conditions vowel lengthening; comparing (6e) with (6f) we see that the specification for tone on the suffix vowel is not affected by the FSC.

(6) a. [ɲāal] ▶
/ɲāal/
'girl'

b. [cōʊl] ▶
/ᴹcōʊl/
'Chol'

c. [ɯą́n ʧjābą́ ɲāal] ▶
/ɯą́n ʧjāp-ą́ ɲāal/
PR.ISG touch-ISG girl
'I am touching the girl.'

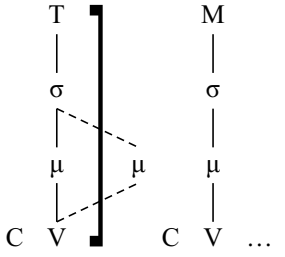
d. [ɯą́n ʧjābą́ą̣ cōʊl] ▶
/ɯą́n ʧjāp-ą́ ᴹcōʊl/
PR.ISG touch-ISG Chol
'I am touching Chol.'

e. [ɯą́n cwêaadą̀ ɲāal] ▶
/ɯą́n cwéaat-ą̀ ɲāal/
PR.ISG kiss.teeth.at-ISG girl
'I am kissing teeth at the girl.'

f. [ɯą́n cwêaadą̀ą̣ cōʊl] ▶
/ɯą́n cwéaat-ą̀ ᴹcōʊl/
PR.ISG kiss.teeth.at-ISG Chol
'I am kissing teeth at Chol.'

Given the data in (6), we hypothesise that with the Mid-toned nouns, the FSC consists of *quantity* only.[8] This is shown schematically in (7). Note that the stem syllable of the noun with the FSC in (7) is specified for the M(id) tone, and the FSC does not include a tone target. This contrasts with the configuration where the stems syllables of FSC nouns are either L(ow) or H(igh) toned in which case the FSC is specified for H(igh) tone, as in (4).

(7)



[8]Ongoing investigations show that the absence of the floating High tone in nouns with the Mid-toned stems may be derived rather than underlying.

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The analysis of Mid-toned nouns that have the FSC indicates that the increase in duration cannot be attributed to the effect of the floating High tone alone: even when the FSC does not condition tone change, it still induces vowel lengthening.

So far, the description has been limited to the phonological footprint of the FSC following an open syllable. The FSC also affects the phonological form when the preceding syllable is closed. An important difference with what we saw up until now is that in the context of the closed preceding syllable, only the floating tone can cross the syllable boundary, but not the floating mora. This is shown in (8), where we again contrast the nouns /gàt/ 'child' (in (8a) and (8c)) and /ᵘ́dɔ̀k/ (in (8b) and (8d)). The FSC does not affect the vowel length of verbs with either short vowels (as in (8a) and (8b)) or long ones (as in (8c) and (8d)). The floating tone, on the other hand, is still able to associate with the preceding closed syllable. This is shown in (8b), where the underlyingly Low-toned verb is realised with a surface rise before the noun with the FSC. When the preceding context is High-toned (as in (8d)), the floating High associates vacuously, just as with the open High-toned syllables in (2d) and (5d).

(8) a. [kɛ̰̀t gàt] ▶
/kɛ̰̀t gàt/
swim.FIN child
'The child is swimming.'

b. [kɛ̰̀t dɔ̀k] ▶
/kɛ̰̀t ᵘ́dɔ̀k/
swim.FIN Dok.person
'The Dok person is swimming.'

c. [ŋwɔ̰̀ŋ̰ŋ gàt] ▶
/ŋwɔ̰̀ŋ̰ŋ gàt/
be.smelly.FIN child
'The child is smelly.'

d. [ŋwɔ̰̀ŋ̰ŋ dɔ̀k] ▶
/ŋwɔ̰̀ŋ̰ŋ ᵘ́dɔ̀k/
be.smelly.FIN Dok.person
'The Dok person is smelly.'

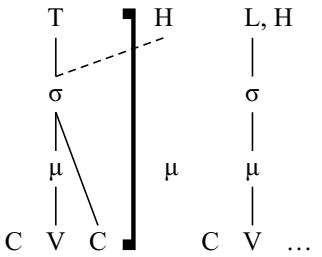
This effect of the FSC on the preceding closed Low-toned syllable is the same for High-toned nouns with the FSC. This is shown in (9): the FSC in (9b) does not induce a vowel length increase, but it does condition a rising tone when the preceding verb is Low-toned.

(9) a. [kɛ̰̀t kɔ̰́m] ▶
/kɛ̰̀t kɔ̰́m/
swim.FIN insect
'The insect is swimming.'

b. [kɛ̰̀t kṵ́m] ▶
/kɛ̰̀t ᵘ́kṵ́m/
swim.FIN hat
'The hat is swimming.'

The schematic representation of the behaviour of FSC nouns with either a Low or a High tone on the stem syllable in the context of the closed preceding syllables is shown in (10). Only the High tone gets associated with the preceding syllable. The coda consonant represents the right edge boundary of the syllable, which the floating mora cannot cross.

(10)



The Mid-toned nouns with the FSC do not contribute any tonal specification to a preceding closed Low-toned syllable, as is shown in (11b). In this respect, the Mid-toned nouns with the FSC behave in a consistent way across all contexts considered in this study (cf. (6d), (6f)).

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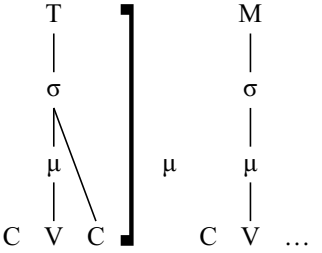
(11) a. [kɐ̣̀t ɲāal] ▶
/kɐ̣̀t ɲāal/
swim.FIN girl
'The girl is swimming.'

b. [kɐ̣̀t cō̱ʊl] ▶
/kɐ̣̀t ᵘcō̱ʊl/
swim.FIN Chol
'Chol is swimming.'

In relation to FSC nouns with Mid-toned stem syllables, we have postulated that the FSC contains a floating mora, but no floating tone. Hence, the schema in (7) above can be extended to context where the preceding syllable is closed, shown in (12). The floating mora does not associate with the preceding context, just as in (10).

(12)



If a preceding finite verb is specified for High tone, then yet another manifestation of the FSC can be observed. It occurs when the following noun is High-toned, as in (13). Nouns that do not have the FSC, as in (13a), are subject to dissimilatory lowering – a sandhi process that changes the second of two High tones into a phonological Low tone (Reid 2019: 152; 2021).[9] But when a noun with a High-toned stem syllable contains the FSC, as in (13b), dissimilatory lowering does not apply. We hypothesise that the floating High tone that is part of the FSC blocks the application of dissimilatory lowering on the noun stem. The two underlying High tones associated with the noun in (13b) are treated as separate specifications by the sandhi process (indicating that the OCP does not apply between the High tone of the FSC and the High tone of the noun stem). This provides further support for our analysis that postulates a High tone as part of the FSC and independent from the tonal specification on the following stem syllable.

(13) a. [ŋwɔ̰̰̰ŋ kɔ̰̀m] ▶
/ŋwɔ̰̰̰ŋ kɔ̰́m/
be.smelly.FIN insect
'The insect is smelly.'

b. [ŋwɔ̰̰̰ŋ kṵ̱m] ▶
/ŋwɔ̰̰̰ŋ ᵘ́kṵ̱m/
be.smelly.FIN hat
'The hat is smelly.'

Schematic representations for the examples (13a) and (13b) are presented below in (14a) and (14b), respectively. Example (14a) shows how dissimilatory lowering applies in (13a): the High tone becomes Low in the context of the High tone of the preceding syllable. Example (14b) shows how the FSC blocks the application of the dissimilatory lowering in (13b): now it is the floating High tone of the FSC that dissimilates to Low, shielding the High tone on the stem syllable. Neither the weight unit nor the resulting Low tone associate with the preceding context.

[9]Dissimilatory lowering is restricted to certain syntactic contexts, including when the subject occurs in post-verbal position as in (13). Dissimilatory lowering does not apply in the context where a suffixed verb is followed by an object (see, e.g., (5c) and (5d)). It equally does not apply across the boundary which separates the topicalised pronoun, for example, /uɻ́n/ 'I' in (5e) and (5f); hence the High-toned verb in these examples is not subject to dissimilatory lowering. Sandhi rules that are sensitive to morphosyntactic conditions have been reported for other related languages (see Remijsen & Ladd (2008: 199–201) for Dinka and Reid (2010: 156–192) for Reel).

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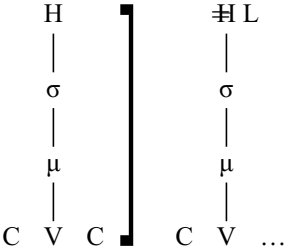
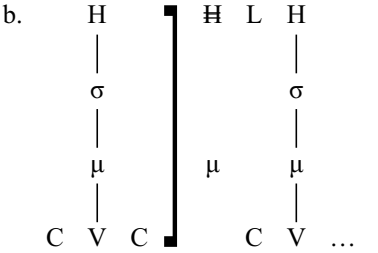
(14) a. 

b. 

Other than /CV/ and /CVC/ preceding contexts, there can be open syllables with phonologically long vowels in Nuer (/CVV/). If a following word has the FSC, these long vowels do not lengthen. We hypothesise that this is due to the vowel contrast in open syllables being maximally binary in Nuer (see fn. 5).

In summary, we hypothesise that the FSC consists of a floating mora and a High tone. The FSC is manifested in the surface phonology only when there is a preceding context: in utterance-initial position, the presence of the FSC cannot be observed at all. When the preceding context consists of a short vowel, the FSC has two effects. First, this preceding vowel increases substantially in duration. Second, if this syllable is Low-toned, it is realised with a rising contour tone instead. This holds for nouns with the FSC that have either a Low or a High tone on the stem syllable. When a noun with the FSC has a Mid tone on the stem syllable, the effect is limited to an increase in duration of the preceding short vowel. If a noun with the FSC is preceded by a closed syllable, the floating tone can associate, but the floating mora cannot. Finally, the High floating tone blocks the application of dissimilatory lowering sandhi on the High-toned nouns with the FSC.

At the basis of this analysis are auditory impressions regarding the duration and melody of the vowel that precedes nouns with and without the FSC. These impressions are subjective, and it is therefore worthwhile to corroborate them – all the more so because the postulated FSC is typologically unusual in that it involves a component of quantity which crosses word boundary. To that end, we have carried out a production study in which we evaluate the central phonetic facts. Specifically, we assess whether a word-final vowel preceding a noun with the FSC is longer and has higher pitch than such a vowel preceding a noun without the FSC. We also examine the interaction of the FSC in the context involving closed preceding syllables to verify our descriptive account of the dissimilatory lowering.

3. Methodology

In this section, we describe the methodology of our production study. The study is based on nouns with and without the FSC. These nouns are described in §3.1, along with the contexts in which the data were elicited. These materials were elicited from a representative sample of speakers of Nuer, described in §3.2. Section 3.3 describes the procedure through which the materials were elicited from the speakers and audio recorded. Then we describe how the resulting data were processed and measured (§3.4) and subjected to statistical analysis (§3.5).

3.1. Materials

The materials include a total of 22 nouns, shown in Table 1.[10] These 22 items diverge as a function of two factors: i) whether the noun has the FSC; and ii) whether the specification for tone on the stem syllable of the noun is Low or High. The FSC is included in the design because, according to our

[10]We originally designed our data set to include 26 nouns. Four of these were discarded after data collection because the phonological form of the words was not consistent across speakers. Specifically, due to the dialect differences within the Lou Nuer dialect cluster, one word had the FSC for half of the speakers but not for the other half; the remaining three words displayed between-speaker variation with respect to the stem vowel and the stem-final consonant.

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Table 1. *The nouns used in the production study, broken down by specification for FSC and tone on the stem syllable*

	Low (10 items)		High (12 items)	
FSC (11 items)	▶ˊcə̀h	'tick'	▶ˊɟɛ́ɛp	'pocket'
	▶ˊcìɛh	'metal bracelet'	▶ˊkɪ́ʈ	'traditional bag'
	▶ˊɟèepnɪ́	'pockets'	▶ˊkʊ́m	'hat'
	▶ˊkèaj	'greater honeyguide (*Indicator indicator*)'	▶ˊlát̪	'cotton'
			▶ˊʈáak	'bowl'
	▶ˊŋɛ̀aʈ	'ash'	▶ˊtwɛ́j	'container for storing grain'
no FSC (11 items)	▶ gàt	'child'	▶ díɪt	'bird'
	▶ ɟɔ̀k	'back'	▶ kɛ́r	'calabashes'
	▶ kɛ̀tnɪ́	'sticks'	▶ kʊ́m	'insect'
	▶ kèaaj	'sacred garlic pear (*Crateva adansonii*)'	▶ kwʌ́n	'food'
			▶ lʊ́k	'court case'
	▶ lìɛt	'sand'	▶ mʊ́k	'buffalo'

descriptive analysis, it determines the duration and fundamental frequency (f0) of the preceding vowel. We tested this by including 11 nouns with the FSC and 11 without. The tone of the stem syllable is manipulated (Low *vs.* High) to demonstrate that it does not affect the surface realisation of tone on the preceding context. Our data set thus includes 10 nouns that have a Low tone on the stem syllable, and 12 that have a High tone.

The nouns were elicited in three contexts, which differ in the opportunity they offer for the FSC to be realised: i) preceded by a short vowel that carries a High tone; ii) preceded by a short vowel that carries a Low tone; and iii) preceded by a closed syllable with a High tone. These contexts are illustrated in (15a), (15b) and (15c), respectively. Preceded by a High-toned vowel (15a), only the vowel duration is affected, but not the f0 (the High tone target of the FSC associates vacuously). The context in (15b) has the nouns preceded by a Low-toned vocalic suffix. The suffix has a High tone underlyingly but it dissimilates to Low due to dissimilatory lowering (see fn. 9). Here, we expect the phonetic realisation of this preceding vowel to be affected by the FSC both in vowel duration and in f0. When the preceding context is a High-toned closed syllable (15c), neither the floating quantity nor the floating tone associate leftward. Instead, we hypothesise that the FSC blocks dissimilatory lowering of the High tone on the stem syllable of the noun.

(15) a. [ɯ́ʌ́n ʈ̪jābɑ́ʌ́ kʊ̪́m] ▶
/ɯ́ʌ́n ʈ̪jāp-ʌ̪́ ˊkʊ̪́m/
PR.ISG touch-ISG hat
'I am touching the hat.'

b. [ɯ́ʌ́n cwɛ̂aadʌ̀ʌ́ kʊ̪́m] ▶
/ɯ́ʌ́n cwɛ́aat-ʌ̪̀ ˊkʊ̪́m/
PR.ISG kiss.teeth.at-ISG hat
'I am kissing teeth at the hat.'

c. [ŋwɔ̋ɔ̋ŋ kʊ̪́m] ▶
/ŋwɔ̋ɔ̋ŋ ˊkʊ̪́m/
be.smelly.FIN hat
'The hat is smelly.'

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3.2. Speakers

The materials were collected from eight native speakers (five female, three male) of Lou Nuer. The youngest speaker was 35 and the oldest was 50 years of age at the time of the recording. All speakers were born in the Lou Nuer region and lived there well into their adolescence. At the time of the recording, all of the speakers resided in Kenya, where they live in close-knit Nuer communities and use Nuer daily. All speakers additionally speak English as a second language.

3.3. Data collection procedure

The data for the production study were collected between September 2021 and February 2022 using a hybrid online/in-person approach. The first author met with the speakers individually through video calls, while a native-speaker research assistant, Rebecca Nyawany Makwach, recorded the speakers in their homes in Nairobi.[11] The recordings were made using a solid-state recorder (Marantz PMD661) and a dynamic headset-mounted microphone (Shure SM10A).

During the recording sessions, the first author communicated with the speakers in English. Additionally, the speakers were able to get explanations in Nuer from the research assistant at any point before, during or after the recording session. Data collection was preceded by the informed consent procedure and a short practice session during which the speakers practiced translating the words and uttering them naturally in the three contexts.

The nouns in Table 1 were elicited in a semi-randomised order, which was reversed for half of the speakers to balance out order-of-presentation effects. Lexical items that are easier to elicit were positioned at the beginning of the set. For each noun, the first author presented the speaker with its English translation and asked the speaker to translate it into Nuer. Where the speaker could not think of the intended Nuer word, the research assistant provided explanation in Nuer without uttering the target word. For example, for /kɛ̀aaj/ 'sacred garlic pear', the research assistant would explain that it is a tree that provides a lot of shade and that it is frequently found around the town of Nasir. This way the speakers were able to recall the intended word (for an example of elicitation sessions see video recordings in Reid 2022a). We started out by recording target nouns in isolation to reassure ourselves that they did not start with a vowel. The word was then elicited in the three contexts in the order shown in (15). We recorded two to three repetitions for each context utterance to maximise the chances of getting a good-quality realisation.

Most speakers were able to carry out the task successfully after a short practice before the actual recording. In addition to the eight speakers who completed the task successfully, we attempted data collection with three other speakers, who struggled either to produce the target words in the contexts, or to utter the utterances in a natural manner. The data from these speakers are not included.

The design thus consists of 22 nouns in the isolation form and in the three contexts across eight speakers. We do not report on the isolation context which was collected merely to ascertain that the words with the FSC are not vowel-initial.[12] Hence, the expected number of utterances in the data set is 528 (22 nouns × 3 contexts × 8 speakers). Because of accidental gaps, however, the actual number that we have in our data set is 505. These 23 gaps are spread across items, contexts, and speakers.[13] Together with the repetitions, the number of the utterances in the data set is 1,371.

[11] Rebecca was also the reference speaker and one of the speakers for this study.

[12] However, the citation context is included in the data set, which is publicly available on Edinburgh Datashare (Reid & Remijsen 2023), so that the reader can verify that the FSC words uttered in isolation are not vowel-initial.

[13] Taken together, the greatest number of accidental gaps for any speaker (L23) is 8 out of 66, and the greatest number of gaps for any item ('sand') across all speakers and contexts is 9 out of 24. The following items are missing from the open syllable preceding contexts (15a,15b): /lìɛt/ 'sand' is missing for speakers L21, L22 and L23; /kɛ̀aaj/, 'sacred garlic pear' is missing for speaker L23, /ᵘ́kɛ̀aj/ 'greater honeyguide' is missing for speaker L13, /kɛ́r/ 'calabashes' is missing for speaker L15, and /kɛ̀tń̩/ 'sticks' is missing for speaker L15. This adds up to 14 missing values (7 gaps across speakers × 2 contexts). The following items are missing for the context with a closed preceding syllable (15c): /lìɛt/ 'sand' is missing for speakers L21, L22 and L23, /kɛ́r/ 'calabashes' for speaker 15, /ᵘ́kɛ̀aj/ 'greater honeyguide' is missing for speakers L13 and L23, and /kɛ̀tń̩/ 'sticks' is missing for speakers L15; the rest of the gaps are in the data for speaker L23: /ᵘc̩ɛ̀h/ 'tick', /kɛ̀aaj/, 'sacred garlic pear'. This accounts for the remaining nine missing values.

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3.4. Data processing

The data were processed using Praat (Boersma & Weenink 2005). First, the utterances of the three types illustrated in (15) were extracted from the raw recording. Because the speakers were asked to repeat each utterance, this yielded two or three realisations (repetitions) for each utterance per speaker. All realisations were included in the study unless they had background noise or hesitation. Second, the sound files were segmented. Specifically, we determined the beginning and the end of both the onset and the nucleus of the stem syllable of the noun. Further segmentation is specific to context environment. In the two contexts where an open syllable precedes the noun ((15a) and (15b)), we segmented the onset and nucleus of this preceding open syllable, as well as the nucleus of the preceding verb stem syllable. And in the context where a closed syllable precedes the noun (15c), the onset, nucleus and coda of this preceding closed syllable were segmented. The segmentation of speech segments in closed- and open-syllable contexts is illustrated in (16a) and (16b), respectively, where the vertical lines represent segment boundaries.

(16) a. [ɰʌ̤́n t̪j|ā|b|ʌ̤́ |d|íɪ|t]
PR.ISG touch.ISG bird
'I am touching the bird.'

b. [ŋw|ɔ̤́ɔ̤|ɲ |d|ìɪ|t]
be.smelly.FIN bird
'The bird is smelly.'

Segmentation was guided by the principles in Turk *et al.* (2006). As a rule, the beginning of the F2 track was taken as the point for placing the segmentation boundary between the vowel and the adjacent consonants. The burst/aspiration phase and the voicing phase at the boundary between a plosive and a vowel were segmented as part of the consonant. In complex onsets (consisting of a stop consonant and a glide [w] or [j], and always followed by non-high vowels in the data), the boundary was placed at the point where F2 begins to transition from the glide into the vowel. Coda [j] and [w] were segmented at the beginning of F1 and F2 transitions from the preceding vowel; at this point, there was also evidence of weaker energy in the spectrogram. [ɰ] in coda position was segmented at the point where the F1 and F2 start going down. The presence of [ɰ] was also evident from the weaker energy in the spectrogram, and presence of noise. Speakers differed in this respect: with some, the weaker energy in the formants was the most salient acoustic landmark; with others, it was the shift in F1 and F2; and with others yet, it was the end of formants and beginning of the noise.[14] Nasals were segmented at the point of the beginning of the anti-formant. With nasals before and after the vowels, in addition to the presence of the anti-formant there is also less energy in the spectrogram compared to that of the vowels. This change in the energy in the spectrogram was also taken as a guiding principle during segmentation. Two nasals with the same place of articulation in a row were segmented at the point of a break between the anti-formants. Whenever the nasals differed in place of articulation, the anti-formants appeared at different levels. In such cases there was also a gap in the anti-formants at which point the segmentation boundary was placed. The lateral in context (15c) has a very distinctive realisation compared to the nasal /ɲ/ that precedes it (the nasal has the anti-formant, the lateral does not), and as such was relatively easy to segment.

Two phonetic parameters were measured: duration and f0, both using scripts.[15] We measured the duration of the suffix vowel in contexts (15a) and (15b) where this vowel preceded words with and without the FSC. The f0 was measured over the noun and the immediately preceding segments: the vocalic suffix in contexts (15a) and (15b), and the stem syllable in context (15c). Two types of f0 measurements were carried out. First, we created time-normalised f0 traces by taking 10 equidistant measurements within each segment starting from the vowel in the stem syllable of the verb and up to and including the vowel of the stem syllable of the noun. Second, we took f0 measurements in the suffix

[14] Often the noise for the consonant following the vowel started around the F3 region whilst the F1 and F2 for the vowel would continue. In such cases we used F2 as a criterion. In terms of vowel durations, it might be that segmenting at the point where the noise begins is more accurate.

[15] The f0 traces were also visually checked for tracking errors.

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vowel and in the vowel of the noun stem. With respect to the suffix vowel, we took the measurements at the temporal mid point of the vowel as well as at 20% and 80% into the suffix vowel's duration. A measurement of the f0 change was subsequently calculated by subtracting the value at 80% from the value at 20%. With respect to the stem vowel of the noun, we took f0 measurements at the temporal mid point and at 20% and 80% into the vowel duration.

3.5. Statistical analysis

The statistical analyses were carried out in R (R Core Team 2021) using the additional packages `tidyverse` (Wickham *et al.* 2019), `lme4` (Bates *et al.* 2015), `lmerTest` (Kuznetsova *et al.* 2017) and `MASS` (Venables & Ripley 2002). All the descriptive statistics reported below were first aggregated over repetitions. This equally applies to all of the figures. The measurements for duration and f0 over the suffix vowel were *z*-transformed by speaker to normalise for between-speaker variation in rate of speech and f0 register. These *z*-transformed values form the basis of the descriptive statistics presented in §4.

In addition, we used linear mixed effects modelling, with the FSC, the tone of the stem syllable of the noun, and the tone of the preceding vowel as fixed factors, and both speaker and item as random factors. In these inferential tests, the dependent variables – duration and f0 – are included as raw values rather than after *z*-transformation. In modelling the random factors, we started out from the maximal model, with random slopes for the three-way interaction between the three fixed factors modelled for both speaker and item (Barr *et al.* 2013). From this starting point, we took out interactions and factors from the random effects structure when the correlations were above 0.9 or below −0.9. Pruning down in this manner, we ended up with item modelled as a random intercept, and speaker modelled as a random slope by the tone of the stem syllable. This random effect structure is used both in the linear mixed effects models for duration and for f0. In these tests, we set the significance threshold (alpha) at 0.01.

Finally, we use linear discriminant analysis (LDA; Vannatta & LaVeni 2020) to determine to what degree duration is effective in predicting category membership for the FSC. This is useful because it has a bearing on how salient the FSC is in the acoustic signal, and therefore how accessible the FSC may be to a native-speaker listener.

4. Results

In this section, we report on the results of the production study. Section 4.1 presents the duration measurements, and §4.2 the f0 measurements.

4.1. Duration

The measurements reported in this section relate to the duration of the suffix vowel that precedes the target nouns, that is, contexts (15a) and (15b). Figure 1 shows means and standard deviations for the duration of this suffix vowel with and without the FSC. The mean values are 77 ms without the FSC and 122 ms with the FSC, a difference of 45 ms. In other words, the suffix vowel is 58% longer in duration when it is affected by the FSC. Figure 1 shows that the distributions are well separated: there is no overlap at the level of one standard deviation, that is, around 68% of the values. This difference is comparable to the one between short and long vowel phonemes: Reid (2024) reports a difference of 47 ms between the short and long vowels in closed stem syllables in utterance-medial context.

Aside from the presence *vs*. absence of the FSC, the variability around the mean is affected by the difference in rate of speech between speakers. The contribution of this factor is evident in Figure 2, which shows the duration measurements broken down by speaker and FSC. The distributions for the duration of the suffix vowel with and without the FSC are more than two standard deviations apart for six out of the eight speakers (Speakers 1, 2, 5, 6, 7, 8), and overlap in standard deviations with and without FSC is limited to a single speaker (Speaker 4).

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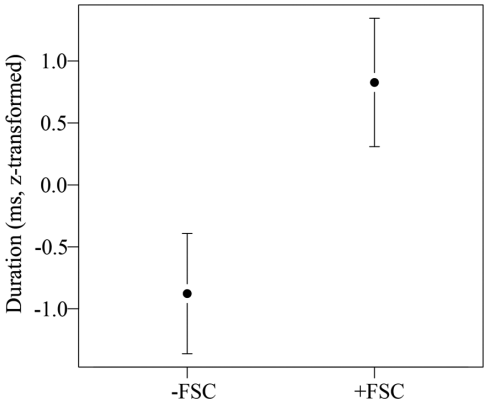

Figure 1. *Means (dots) and standard deviations (whiskers) for the duration of the suffix vowel (z-transformed by speaker) as a function of the FSC on the following noun, across all speakers and items.*

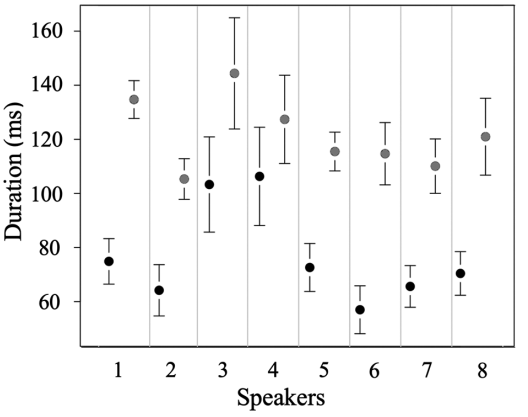

Figure 2. *Means (dots) and standard deviations (whiskers) for the duration of the suffix vowel as a function of the FSC, for each of the eight speakers separately. Black dots – without the FSC; grey dots – with the FSC.*

Figures 1 and 2 demonstrate that the duration of the suffix vowel is determined by presence or absence of the FSC on the noun that follows the suffix. Figure 3 explores whether its duration is additionally influenced by the specifications for tone on i) the following noun (Figure 3a) and ii) the suffix itself (Figure 3b). Overall, the suffix has greater duration as a function of Low tone – either on the noun stem or on the suffix itself. In Figure 3a, the mean durations of the suffix vowel without the FSC are 75 ms and 79 ms for nouns with High *vs.* Low-toned stem syllables, respectively. With the FSC, the mean durations are 119 ms and 126 ms for nouns that have High *vs.* Low-toned stem syllables, respectively. In Figure 3b, the mean durations of the suffix vowel without the FSC are 76 ms and 77 ms for nouns preceded by High *vs.* Low-toned suffixes, respectively. With the FSC, the mean durations of the suffix vowel are 120 ms and 124 ms for nouns preceded by High *vs.* Low-toned suffixes. However, as can be seen from Figure 3, neither the specification for tone on the noun stem nor the specification for tone on the suffix vowel itself exert a sizeable influence on the duration of the suffix vowel.

We ran a linear mixed effects model, with FSC, Noun Stem Tone, and Suffix Tone as fixed factors, including all of the possible interactions between them. Item was modelled as a random intercept, and

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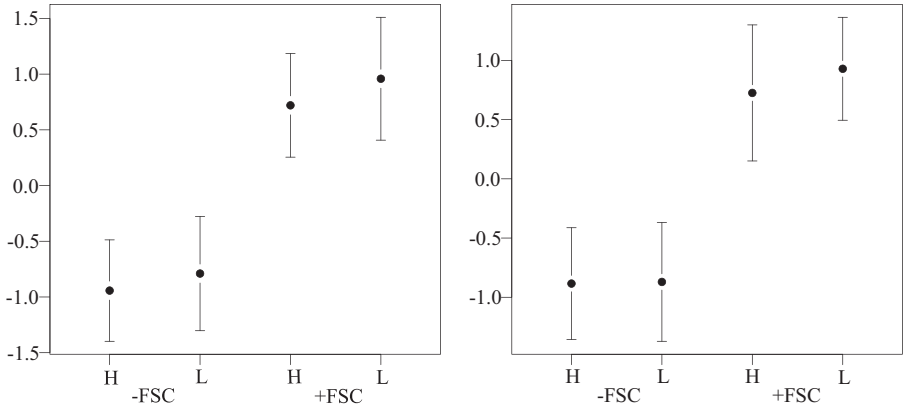

(a) FSC × Noun Stem Tone (b) FSC × Suffix Tone

Figure 3. *Means and standard deviations for the duration of the suffix vowel as a function of the FSC (z-transformed by speaker), broken down by Noun Stem Tone (a) and Suffix Tone (b).*

Table 2. *Results of the linear mixed effects model for duration as a function of FSC, Noun Stem Tone and Suffix Tone. Significant results are marked by asterisks*

	Sum of squares	df	*F*	Probability
FSC	0.059675	1	369.38	< 0.0001*
Noun Stem Tone	0.000063	1	0.39	0.5391
Suffix Tone	0.000009	1	0.05	0.8141
FSC × Noun Stem Tone	0.000025	1	0.15	0.6993
FSC × Suffix Tone	0.000715	1	4.4	0.0357
Noun Stem Tone × Suffix Tone	0.000248	1	1.5	0.2159
FSC × Noun Stem Tone × Suffix Tone	0.000827	1	5.12	0.0239

Speaker as a random slope by Noun Stem Tone. The resulting model is reported in Table 2.[16] As seen in Table 2, the effect of FSC on duration is highly significant. None of the other factors reach the significance threshold of 0.01, although the interactions involving FSC and Suffix Tone are almost significant. In summary, the results of the linear mixed effects analysis support the hypothesis that the FSC conditions a substantial difference in the duration of the preceding suffix vowel.

Further evidence in support for this conclusion comes from a LDA with the FSC as the factor to be classified based on the duration of the suffix vowel (*z*-transformed by speaker to correct for variation in rate of speech). As the factor, FSC has two levels, the LDA generates one discriminant function. The correlation coefficient (*r*) of the duration measurement with this function is 1.85. A total of 95% of the tokens were classified correctly for the FSC, indicating that nouns can be classified reliably for FSC on the basis of the duration of the preceding vocalic suffix.

In this section, we have reported on the effect of the FSC on the duration of the vowel of a preceding open syllable. We do not perceive a difference in the duration of the vowel in a preceding closed syllable as function of the FSC across the following word boundary, and earlier studies have not reported such a difference either. Examining the duration of the stem vowel of the verb in the consonant-final preceding context, that is, (15c), we find mean values across speakers and items of 92.6 ms without the FSC and

[16]The formula for this model in R is `lmer(duration ~ FSC * Noun.Stem.Tone * Suffix.Tone + (1 + Noun.Stem.Tone|Speaker) + (1|Item), data=Duration.Dataset)`.

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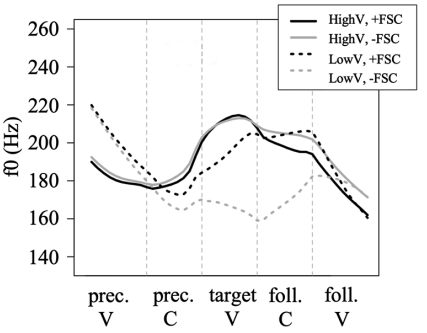

Figure 4. *Time-normalised f0 traces over the domain extending from the vowel of the preceding verb stem up to and including the stem vowel of the noun, averaged over all items and speakers. Separate lines by tone of the preceding suffix vowel and the FSC (see legend).*

of 92 ms with the FSC. In the light of these findings, we are not examining the duration of this vowel further.

4.2. Fundamental frequency (f0)

4.2.1. With nouns preceded by vocalic suffix

We start with exploring f0 through time-normalised f0 traces averaged over all speakers, and then proceed to extract measurements informed by these observations. While time-normalised f0 traces do not show the realisation of the FSC in terms of duration, they enable us to gauge its melodic realisation, as a mean value across the speakers and items in our sample. Figure 4 shows time-normalised f0 traces separated out by the FSC and by the tone of the preceding suffix vowel. If the suffix is High-toned underlyingly, f0 over the suffix is high, both without the FSC (solid grey line) and with the FSC (solid black line): the traces for these conditions overlap over the suffix vowel. In contrast, if the suffix carries a Low tone, the f0 traces differ depending on whether the following noun has the FSC or not. In the context without the FSC (dashed grey line), f0 over the suffix is low level; and in the context with the FSC (dashed black line), f0 exhibits a rise over the suffix. This state of affairs suggests that the FSC contributes a High tone target to the vocalic suffix. When the preceding suffix vowel also has a High target, the melodic patterns are indistinguishable. But when the preceding suffix has a Low target, the compositional outcome of this Low target with the High tone of the FSC is a rising contour.

In Figure 5, we examine the interaction between the tone on the preceding suffix and the FSC on the basis of the f0 values at the temporal mid point of the suffix vowel (Figure 5a), and the f0 change over the vocalic domain (Figure 5b) which was calculated by subtracting the f0 value at 80% of the vowel's duration from the value at 20% of the vowel's duration. Figure 5a shows a three-way separation among, first, the condition with a High-toned suffix, where f0 is 212 Hz without the FSC and 213 Hz with the FSC; second, the condition with a Low-toned suffix and the FSC, that is, the rising contour of Figure 4 (dashed black line), which yields an f0 of 194 Hz; and third, the condition with a Low-toned suffix without the FSC, which yields an f0 of 169 Hz. Figure 5b shows the same separation among three patterns: if the suffix is High-toned, the f0 changes little over the duration of the vowel; if the preceding suffix is Low-toned and the noun has the FSC, the f0 is rising (negative f0 change value); and if the suffix is Low-toned and the noun does not have the FSC, the f0 is falling (positive f0 change value). Given that the whiskers encompass one standard deviation (68%) around the mean, and that the measurements are *z*-transformed by speaker to normalise for between-speaker variation in register and range, we can infer from Figure 5 that the separation of these patterns is fairly salient. Comparing the two panels with one another, we can see that the separation of the three patterns is clearer in terms of the f0 change measure (Figure 5b). Hence, we will use the f0 change measure as a dependent in the inferential test reported below.

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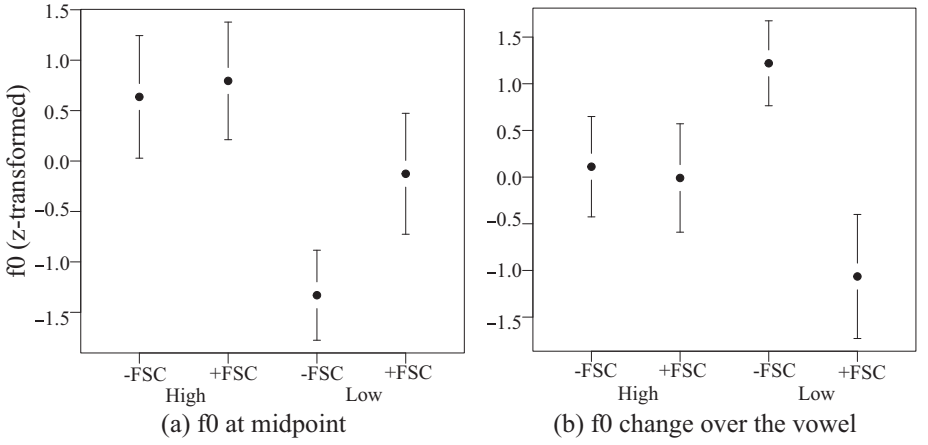

Figure 5. *Means and standard deviations for f0 as a function of Suffix Tone and FSC, measured at temporal midpoint of the vowel (a), and f0 change between 20% and 80% of the vowel's duration (b), across all speakers and items, after z-transformation by speaker.*

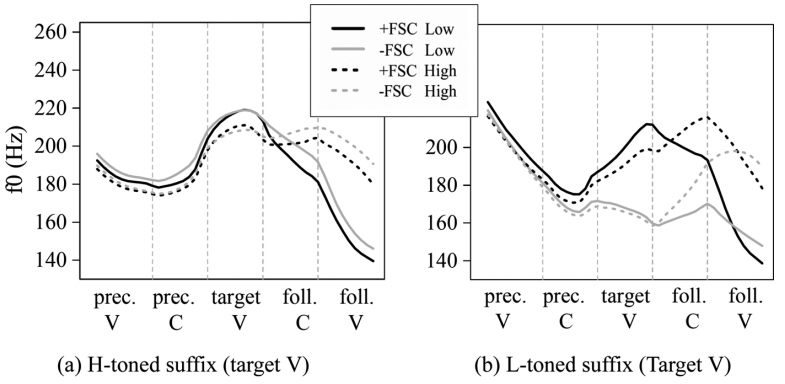

Figure 6. *Time-normalised f0 traces over the domain extending from the vowel of the preceding verb stem ('prec. V') up to and including the stem vowel of the noun ('foll. V'), averaged over all items and speakers. Separate panels by Suffix Tone; separate lines by FSC and by Noun Stem Tone (see legend).*

Having considered the influence of the preceding tonal context, we now examine the influence of the following tonal context, that is, the specification for tone – Low or High – on the stem syllable of nouns with and without the FSC (Figure 6). The results are broken down by the specification for tone on the suffix vowel, the importance of which was established above (Figures 4 and 5). Figure 6a shows that, when the suffix vowel (marked as 'target V') is High-toned, there is no substantial difference between the f0 traces up to the onset of the stem syllable of the nouns ('foll. C'). The specification of the tone on the noun stem begins to determine the f0 trajectory from the onset consonant onwards. When the suffix vowel is specified for a Low tone (Figure 6b), the f0 traces over the suffix vowel diverge as a function of the FSC: they are low level in the absence of the FSC and rising with the FSC. It is only from the onset consonant of the following stem syllable ('foll. C') that the specification for tone of the noun stem conditions the divergence of the f0 traces. Across the conditions of the FSC and the tone of the preceding suffix, f0 is 6 Hz higher when the noun stem has a Low tone than when it has a High tone. This difference is small relative to other sources of variability. Crucially, the f0 traces over the suffix vowel do not diverge substantially as a function of the specification for tone of the stem syllable of the noun.

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Table 3. *Results of the linear mixed effects model for the dependent f0 change as a function of fixed factors: FSC, Noun Stem Tone, Suffix Tone. Significant results are marked by asterisks*

	Sum of squares	df	*F*	Probability
FSC	11496.3	1	436.64	< 0.0001*
Noun Stem Tone	11.3	1	0.43	0.5189
Suffix Tone	10272.3	1	390.15	< 0.0001*
FSC × Noun Stem Tone	374.7	1	14.2	0.001*
FSC × Suffix Tone	22674.8	1	861.21	< 0.0001*
Noun Stem Tone × Suffix Tone	12.2	1	0.46	0.495
FSC × Noun Stem Tone × Suffix Tone	200.0	1	7.60	0.006*

We ran a linear mixed effects model on the f0 measurements, with FSC, Noun Stem Tone and Suffix Tone as fixed factors, including all of the possible interactions between them. In this model f0 is represented as f0 change, because it differs more clearly as a function of FSC and Suffix Tone than static f0 measures (cf. Figure 5). As in the model for duration, Item was modelled as a random intercept, and Speaker as a random slope by Noun Stem Tone. The resulting model is reported in Table 3.[17] The biggest significant effect is due to the interaction between FSC and Suffix Tone. In addition, there are also sizable significant effects for FSC and Suffix Tone by themselves. Then there are smaller significant effects for the interaction between FSC and Tone and the three-way interaction between FSC, Noun Stem Tone, and Suffix Tone. However, Noun Stem Tone is not significant as a main effect. These results support the analysis in §2. Specifically, the f0 pattern on the vocalic suffix is determined primarily by its own specification (Suffix Tone) and by the FSC, which comes with a High tone target. These two factors interact, in the sense that the effect of the FSC is different when the suffix is specified for Low tone or High tone: if the suffix is specified for Low tone, the addition of the High tone target of the FSC yields a rising f0 pattern; if the suffix is specified for High tone, the addition of the High tone of the FSC applies vacuously.

4.2.2. With nouns preceded by closed syllable

We conclude with the examination of the f0 patterns in nouns in the context following a closed High-toned syllable (15c). According to our descriptive analysis (§2), neither the floating mora nor the floating tone dock leftwards in this environment. Instead, the FSC interacts with a tone sandhi process, dissimilatory lowering: High-toned nouns without the FSC undergo dissimilatory lowering in this context, changing High tones on the noun into Low tones; High-toned nouns with the FSC, in contrast, do not.

Figure 7 shows that High-toned nouns without the FSC indeed have low f0 over the onset and nucleus of the stem. The pattern is similar to that of the underlying Low-toned nouns, however, with the latter the fall is somewhat steeper than with the Low that results from the dissimilatory lowering. In contrast, the High-toned nouns with the FSC have high f0 at the beginning of the vowel of the stem syllable.[18] Inspection of the time-normalised traces in the Figure 7 indicates that the divergence is greatest earlier in the vowel. For that reason, further descriptive and inferential statistics relating to dissimilatory lowering are based on this measure.

[17] The formula for this model in R is `lmer(F0.Change ~ FSC * Noun.Stem.Tone * Suffix.Tone + (1 + Noun.Stem.Tone|Speaker) + (1|Item), data=F0.Dataset.A)`.

[18] The realisation of the High tone in Nuer varies depending on the voice quality of the vowel. It is realised as level high f0 if the vowel is breathy, and as a fall if the vowel is modal. Within our data set (Table 1), roughly half of the nouns have a modal vowel which gives rise to the somewhat falling average realisation of the High-toned nouns.

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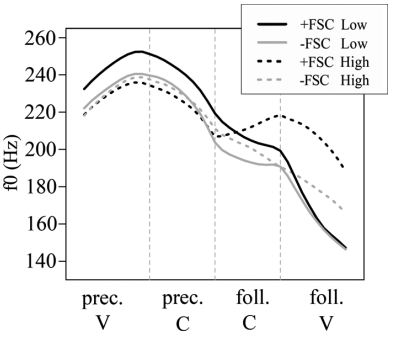

Figure 7. *Time-normalised f0 traces over the domain extending from the vowel of the verb stem ('prec. V') up to and including the stem vowel of the noun ('foll. V'), averaged over all items and speakers. Separate lines by FSC and by Noun Stem Tone (see legend).*

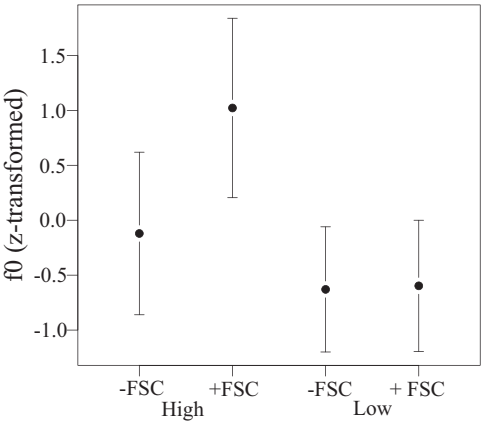

Figure 8. *Means and standard deviations for f0 taken at 20% into the vowel of the noun stem in the context preceded by a closed High-toned syllable, z-transformed by speaker and across all speakers and items, as a function of FSC and Noun Stem Tone.*

In Figure 8, we show the effect of dissimilatory lowering on the High-toned nouns without the FSC and the absence of this effect in the High-toned nouns with the FSC where the dissimilatory lowering is blocked by the floating High tone. The mean value for the High-toned nouns without the FSC that are subject to dissimilatory lowering is 189 Hz. This mean is closer to the f0 of the Low-toned nouns (180 Hz without the FSC, and 182 Hz with the FSC) than to the f0 of the High-toned nouns with the FSC which is 212 Hz. However, there is a lot of overlap in the standard deviations with both the high and the low levels. This suggests that dissimilatory lowering does not result in a complete neutralisation with the Low tone.

We ran a linear mixed effects model on the f0 measurement for the stem syllable of the noun, with FSC and Tone (of the noun stem) included as fixed factors, plus the interaction between them. (The tone of the preceding verb stem is not included as a factor because it is invariably High.) The dependent is the f0 at 20% into the vowel (cf. Figure 8). As in the earlier models, Item was modelled as a random intercept, and Speaker as a random slope by Noun Stem Tone. The resulting model is reported in Table 4.[19] FSC and the interaction between Noun Stem Tone and FSC register a significant effect, and Noun Stem Tone itself is almost significant at 0.01. This is in line with the descriptive statistics reported

[19]The formula for this model in R is `lmer(F0.At.20% ~ FSC * Noun.Stem.Tone * Suffix.Tone + (1 + Noun.Stem.Tone|Speaker) + (1|Item), data=F0.Dataset.B)`.

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Table 4. *Results of the linear mixed effects model for the dependent f0 at 20% of the stem vowel as a function of FSC and Noun Stem Tone. Significant results are marked by asterisks*

	Sum of squares	df	*F*	Probability
FSC	4035.1	1	17.14	0.0004*
Noun Stem Tone	1099.9	1	4.67	0.0397
FSC × Noun Stem Tone	2784.6	1	11.83	0.0022*

above. As seen in Figure 8, the biggest difference in the f0 values is conditioned by FSC, as it blocks the neutralisation between Low tone and High tone triggered by dissimilatory lowering. This effect is specific to High-toned FSC nouns, hence the significant interaction.

4.3. Summary

The results of the production study reported in this section show that the FSC conditions a sizeable increase in the duration of the preceding vowel. On average, the duration of this vowel is 46 ms longer before a noun with the FSC (122 ms) than before a noun without the FSC (77 ms), a difference of 58%. This difference is consistent across speakers, to the effect that 95% of the noun tokens can be correctly classified for the FSC on the basis of the duration of the preceding suffix.

The FSC also affects f0 on the suffix vowel, specifically when the vowel is underlyingly specified for Low tone. In this environment, the FSC conditions a rising contour. This finding is in line with the analysis presented in §2, where we postulated that the FSC includes a High target. Finally, the production study confirmed that the FSC interacts with dissimilatory lowering, blocking its application.

5. Discussion: the diachronic development of the FSC in Nuer

Having corroborated the phonetic facts underlying the descriptive analysis of the FSC in §2, we now turn to the question of its diachronic origin. In several West Nilotic languages, both lexical morphemes and inflected words consist primarily of a single closed syllable. A key factor in the drive towards monosyllabism is the loss of suffixes, properties of which have been reassociated within the preceding stem syllable in various ways. First, the ATR specification of the lost vocalic suffixes was transferred to the stem syllable in the guise of specifications for either ATR or voice quality (Mietzner 2007: 146). Second, the tones of lost suffixes also shifted to the stem syllable. This can be seen among other in Shilluk noun paradigms, which can be either suffixed or suffixless. The tonal specification of suffixed paradigms is mirrored in suffixless paradigms, where the same specification is added compositionally onto the stem (Reid 2009: 38–40; Remijsen & Ayoker 2019: 37–42). Finally, the quantity of lost suffix vowels turned into increased vowel length in the stem syllable through compensatory lengthening (Andersen 1990). And because West Nilotic had a two-way vowel length contrast to begin with, this resulted in ternary vowel length contrasts in a number of languages including Dinka (Andersen 1987; Remijsen & Gilley 2008), Reel (Reid 2010), Shilluk (Remijsen *et al.* 2019), and Nuer (Monich 2017; Reid 2019, 2024). Moreover, the quantity of certain lost suffixes was retained as floating quantity in Shilluk (Remijsen & Ayoker 2020, cf. §1.1).

Nuer has gone further in this diachronic development towards a monosyllabic word shape, in that wordinitial segments have also been lost. In its closest relatives, Dinka and Reel, verb stems are already exclusively monosyllabic; among nouns, the monosyllanic template predominates, but there remain polysyllabic stem forms in which a closed monosyllable is preceded by the vowel /a/ (see Storch 2005: 168, Remijsen & Manyang 2009: 114, and Andersen 2014 on Dinka; and Reid 2010; Cien *et al.* 2016 on Reel). Comparative evidence indicates that these are the forms out of which the FSC has developed. This is shown in Tables 5 and 6, which display words that have the FSC in Nuer alongside cognates in

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Table 5. *Cognate nouns in Nuer and Dinka. Dinka data come from the second author's own research*

Nuer (SG – PL)	Dinka (SG – PL)	
ˊcwɛ̀aah – ˊcwɛ́àaaɯ	acwɛ̌eek – acwɛ̀ek	'twin'
ˊɟwàj – ˊɟwáàaj	aciwjɛ̀ɛj – aciwìij	'grass' (Nuer); 'rope made of grass' (Dinka)
ˊtu̱ɔ̱ɔ̱ – ˊtu̱ʊ̱ʊ̱ɯ	adwɔ̰̀ɔk – adɔ̰̀ook	'k.o. gourd'
ˊgórgór – ˊgóɔ̀rgɔ̀ɔɔɔrɪ̱	agɔ̀oor – agór	'pumpkin seed'
ˍtɔ̱̄ɔ̱ɔ̱r – ˊtɔ̱a̱rɪ́	agɔ̰̀r – agɔ̰̂oor	'river bank'
ˊgɔ́ɔɔk – ˍgɔ̄agnɪ́	agɔ́ɔɔk – agɔ̌ɔk	'monkey'
ˍgʊ̱ʊ̱k – ˊgʊ́ɔ̱ɔ̱ʷɯnɪ́	agʊ̰̀uuk – agʊ̰̂k	'dove'
ˊkɪ̱m – ˊkɪ̱̀mnɪ́	akɪ́im – akɪ̀iim	'doctor'

Table 6. *Cognate nouns in Nuer and Reel. Reel data from Cien et al. (2016) are given in Reel standard orthography. Reel data marked with an asterisk come from the first author's own research*

Nuer (SG)	Reel (SG)	
ˊt̪iiiɯ	at̪iiw*	'grass door'
ˊt̪áak	⟨*athak*⟩	'bowl' (Nuer); 'pot' (Reel)
ˊkɔ́al	⟨*akäl*⟩	'calf'
ˊd̪áaar	⟨*adhaar*⟩	'pot'
ˊdáaaŋ	⟨*adaŋ*⟩	'bow'
ˊgáw	⟨*agau*⟩	'ko grass'
ˊlát̪	alâat̪*	'cotton' (Nuer); 'cloth, thread' (Reel)
ˊcàah	⟨*acak*⟩	'cow flea'

Dinka and Reel, respectively, that have an initial vowel /a/. We hypothesise that the FSC in Nuer has its diachronic origin in the loss of these initial vowels.

The diachronic development from lost word-initial vowels to the FSC can be explained as follows: when a vowel-initial word follows a word that ends in a vowel, hiatus ensues, that is, the juxtaposition of two vocalic nuclei without an intervening consonant. Hiatus is an unstable phonological constellation, and languages tend to have one or more processes to 'resolve' it, that is, processes that result in a disappearance of two juxtaposed vowels from the surface-phonological form (Casali 2011). One of the ways in which hiatus can be resolved is through compensatory lengthening, whereby the segmental material is lost but the associated quantity is retained and transferred to another constituent (Hayes 1989; Casali 2011: 2). Casali (2011) gives the following example from the Bantu language Ganda, where /ka-oto/ 'small fireplace', is realised [ko:to]. Note that the first vowel /a/, has been lost, and the second vowel has lengthened 'in compensation'. Hiatus resolution through compensatory lengthening has also been observed in relation to word-initial vowels in another West Nilotic language Shilluk: for example, /já ɔ̀cʌʌʌmɔ̀/ 'PR.ISG IMPF-eat:AP' 'I am eating' is realised as [jáà.cʌʌʌ.mɔ̀] (Remijsen *et al.* 2015: 595–596). Here, the word-initial vowel is lost, and its quantity and tone are transferred to the preceding vowel. These examples, in which a word-initial vowel loses its segmental content while its quantity and specification for tone reassociate with the preceding vowel, indicate how the FSC in Nuer may have developed.

The hypothesised diachronic development of the FSC is illustrated schematically in (17). In the diachronic stage one (17a), the word-initial vowel /a/ is realised in most environments; but in the context of a preceding vowel in /ɟ̪āb-ɲ́/ 'touch-ISG', hiatus is resolved through compensatory lengthening: the vowel /a/ is not realised, and both the quantity and the tone that were associated with this vowel link

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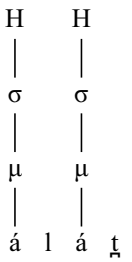
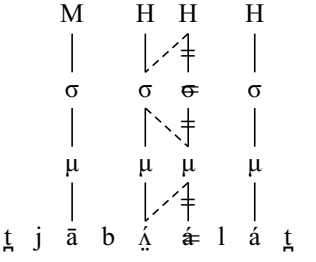
instead within the preceding syllable. In the diachronic stage two (17b), the word-initial vowel is lost, but speakers continue to reproduce the lengthening and tonal effects of the hiatus resolution: the surface phonological realisation is [t̪jāb̪́ʌláat̪] in stage 1 and stage 2 are alike. Because the vowel /a/ is no longer realised, we need to represent these specifications for quantity and tone as FSCs, that is, the FSC.

(17) a. *Diachronic stage 1:* álát̪ *'cotton'*

Underlying form

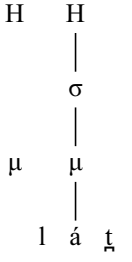


Haitus resolution

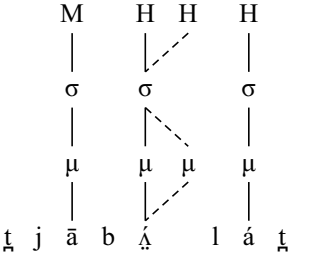


b. *Diachronic stage 2:* ᵘ́lát̪ *'cotton'*

Underlying form



Following a short vowel



The hypothesised development of the FSC out of a hiatus resolution hinges on two theoretical concepts relating to diachronic change. One is the exemplar theory (Wedel 2006; Pierrehumbert 2016): the exemplars with hiatus-induced lengthening are part of the lexical representation of the words with the initial /a/, and they continue to be so when the initial vowels are lost. The other is that the listener misinterprets the source of the increased duration of the preceding vowel as an inherent property of the noun, even though it does not have an initial vowel (Ohala 1989).

Not considered so far is the High tone that is part of the FSC. While the unit of quantity of the FSC in Nuer matches the quantity of the word-initial vowel /a/ in the closely-related Dinka and in Reel (cf. Tables 5 and 6), the High tone of the FSC is not mirrored in the cognates: no tone is postulated for the word-initial vowel /a/ in the Nuer's sister languages. This is because, in Dinka and in Reel, tone is not contrastive in this position. However, at least in some dialects of Dinka, including Bor South, the word-initial vowel /a/ gets a High tone by default in the derivation of the surface-phonological form.[20] In this way, the synchronic evidence on the word-initial vowel /a/ in Dinka offers a scenario of how the FSC in Nuer could have evolved its specification for High tone.

In line with its hypothesised diachronic origin in /a/-initial nouns, the FSC in Nuer is found synchronically only within the lexical category of nouns. In most words that have it, it is a part of the phonological specification of the lexical base. There are certain semantic domains in which the FSC words are common, such as body parts (18a) and terms referring to textiles. However, these are merely tendencies, as seen from the body parts in (18b) which do not have the FSC. It is also worthwhile to note that loan words can have the FSC, even when the source word is not vowel-initial (18c).

[20]For example, all of the following words are realised with a High tone on the initial syllable in Bor South Dinka: [áláat̪] 'cloth' (cf. (17)), [ágòoor] 'pumpkin seed', [ákwɛ̀ɛm] 'bean', [áɲáaar] 'buffalo'.

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(18)	a.	ˊcą̈ą̈ąr 'umbilical cord'	ˍcɔ̱ą̈ą̈ 'bone'	ˊtìɛɛj 'pupil of eye'
	b.	lɔ́ɔc 'heart'	ɟɔ̄k 'back'	kʊ̀ɔc 'ankle'
	c.	ˊcɪ́nṯà 'bag' (< Arabic)	ˊbɛ́ɛk 'bag' (< English)	ˍbʊ̱n 'coffee' (< Arabic)

Since it cannot be predicted if a given noun has the FSC, we postulate that the FSC is part of the underlying specification of the lexical morphemes.

6. Conclusion

Nuer, a West Nilotic language spoken in South Sudan and in Ethiopia, has a FSC. In Lou Nuer, which is under investigation here, the FSC consists of a floating weight unit and a floating High tone, both of which are located at the left edge of the phonological representation of some nouns. The analysis of the FSC in §2 we presented a descriptive analysis of the FSC, spelling out how it affects the surface phonological form in interaction with the phonological properties of the noun itself and of the preceding context. We then confirmed the auditory impressions on which this descriptive analysis is based through a production study with eight native speakers. Comparative evidence indicates that the FSC has its origin in a lost word-initial vowel. We hypothesise that, before the loss of this vowel, the suprasegmental features of quantity and tone of this vowel were isolated from its segmental basis in hiatus resolution. These exemplars continued to be reproduced after the loss of the vowel.

Across the world's languages, floating elements have been postulated in relation to tone (Welmers 1970; Paster 2010), quantity (Trommer 2015; Zimmerman 2017), and various other features (Akinlabi 1996 and further references there). Against this background, our analysis of the FSC in Nuer is of interest in two ways. First, the Nuer FSC is part of the underlying representation of nouns, that is, lexical morphemes, rather than representing (part of) bound morphemes. Second, the weight unit of the FSC is prosodically integrated across a word boundary, associating with a preceding word-final short vowel. As for how these typologically unusual properties have developed, we highlight the strong diachronic drive towards monosyllabism among West Nilotic languages. This diachronic development reaches its culmination in Nuer where the remaining polysyllabic nouns (/a/-initial nouns in Dinka (Table 5) and Reel (Table 6)) have become monosyllabic through the development of the FSC.

The analysis of the FSC in this article is based specifically on the phenomenon as it occurs in Lou Nuer. Other dialects differ with respect to the phonological nature of the FSC. We commend this area of research for further investigation.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0952675724000198. The supplementary materials include sound clips in waveform audio file (wav) format that illustrate the examples presented in the article. Each file is labelled with a number and a letter corresponding to the examples; for example, 1a.wav is the recording of example (1a). Files corresponding to examples in Table 1 include the English translations of the Nuer words in their filenames, for example, Table1_ash.wav.

Data availability statement. The complete data set used in this study is available separately (Reid & Remijsen 2023).

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