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Quantifying written ambiguities in tone languages: A comparative study of Elip, Mbelime, and Eastern Dan

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Whether tone should be represented in writing, and if so how much, is one of the most formidable challenges facing those developing orthographies for tone languages. Various researchers have attempted to quantify the level of written ambiguity in a language if tone is not marked, but these contributions are not easily comparable because they use different measurement criteria. This article presents a first attempt to develop a standardized instrument and evaluate its potential. The method is exemplified using four narrative texts translated into Elip, Mbelime, and Eastern Dan. It lists all distinct written word forms that are homographs if tone is not marked, discarding repeated words, homophony, and polysemy, as well as pairs that never share the same syntactic slot. It treats lexical and grammatical tone separately, while acknowledging that these two functions often coincide. The results show that the level of written ambiguity in Elip is weighted towards the grammar, while in Mbelime many ambiguities occur at the point where lexical and grammatical tone coincide. As for Eastern Dan, with its profusion of nominal and verbal minimal pairs, not to mention pronouns, case markers, predicative markers, and other parts of speech, the level of written ambiguity if tone is not marked is by far the highest of the three languages. The article ends with some suggestions of how the methodology might be refined, by reporting some experimental data that provide only limited proof of the need to mark tone fully, and by describing how full tone marking has survived recent spelling reforms in all three languages.

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1. Introduction[1] When tone is not marked fully[2] in the orthography of a tone language, written ambiguities inevitably occur. But since no orthography succeeds in eliminating ambiguity entirely, how can an orthography developer judge what constitutes an acceptable level of under-representation? To help answer this question this paper compares tonal written ambiguities in the orthographies of three Niger-Congo languages: Elip (Bantu A62, Cameroon), Mbelime (Gur, Benin), and Eastern Dan (Mande, Côte d'Ivoire).

Since written ambiguity is closely related to the concept of functional load, it will help to provide a definition of this term at the outset. King's (1967a:190) definition is probably the most frequently cited:

> The term functional load is customarily used in linguistics to describe the extent and degree of contrast between linguistic units, usually phonemes. In its simplest expression, functional load is a measure of the number of minimal pairs which can be found for a given opposition. More generally, in phonology, it is a measure of the work which two phonemes (or a distinctive feature) do in keeping utterances apart – in other words a gauge of the frequency with which two phonemes contrast in all possible environments.

One of the aims of the analysis presented in this chapter is to demonstrate that it is perfectly valid to address the issue of functional load "in its simplest expression", by presenting lists of tonal minimal pairs. But our analysis goes three steps further than this. It seeks to establish whether the tonal ambiguities, if tone is not marked orthographically in a given language, are weighted towards the lexicon or the grammar. It also systematizes the relationships between the various grammatical ambiguities, paying particular attention to tonal inflection in the verb system. Finally, it proposes a straightforward way for orthography developers to quantify tonal written ambiguities with a view to standardizing procedures and thus enabling cross-linguistic comparison.

2. Functional load

2.1 Literature overview A brief summary of the rest of the literature on functional load will help set the scene. The term can be traced back to the Prague School (Mathesius 1929; 1931; Trubetzkoy 1939), but it was Martinet (1955) who brought it to prominence among Western linguists.[3] Early researchers tended to be concerned with

[1]We would like to thank Baboga Achille, Esseba Ombessa Lambert (Elip), N. Bienvenue Sambiéni, Claire N'Tadé (Mbelime), and Gué Nestor (Eastern Dan) for their help in eliciting and checking the data.

[2]This article uses the term "full tone marking" to designate the strategy, often employed in Africa, of marking one fewer accents than the number of discrete level tones in the language. This is in contrast to "exhaustive tone marking", which we employ to designate the strategy, more common in Asia and Central America, of marking each and every tone.

[3]Early researchers sometimes refer to *functional yield* (e.g., Greenberg 1959; Avram 1964; Corriente 1971) or *functional burden* (e.g., Twadell 1935; Hockett 1950), but these alternatives tend no longer to be used. Martinet, writing in French, uses the term *rendement fonctionnel*.

functional load as it related to diachronic sound change (Hockett 1966; King 1967b; Wang 1967), but others applied it to language acquisition (Brown 1988; 1991; Catford 1987; Ingram 1989; Pye et al. 1987) and dialect comparison (Kies 1986). Early researchers also embarked on a quest for a viable method of quantifying functional load in corpus-based evaluations including Danish (Rischel 1961), Russian and Czech (Kučera 1963), Romanian (Avram 1964), Germanic (King 1967a), Santa Clara Tewa and – closest to the concerns of our own study – Yoruba, Igbo, and Hausa (Greenberg 1959).

However, these early attempts at quantification were largely unsuccessful, and for many years inquiry into functional load fell completely out of fashion. It is only with the advent of computational linguistics that quantification has finally become possible (e.g., Kitahara & Shigeaki 2000; Wedel et al. 2013a; Wedel et al. 2013b). Several studies investigate tone languages (Surendran & Levow 2004; Stokes & Surendran 2005; Munro & Derwing 2006; Surendran & Niyogi 2006; Oh et al. 2013) and some include African languages (Pellegrino et al. 2011; 2012; Coupé et al. 2016).

2.2 Functional load and orthography development What is perhaps less well known is that, throughout this period, researchers developing orthographies for previously unwritten minority languages have always found the concept of functional load to be intuitively reasonable, and frequently evoke it to articulate their ideas (Powlison 1968:79–80, 86–91; Gudschinsky 1970; Gordon 1986:75–78; Cahill 2001:16, 19–20). It is also common for researchers to make passing references to the functional load of tone in individual African languages:

> […] the functional load carried by tone [in Akan] is more frequent at the level of grammar than at the lexical level. (Abena 1985, as cited in Koffi 1994:4)[4]

> In the Grassfields languages the functional load of tone is so important that it would be unreasonable to ignore tone completely. (Mfonyam 1990:23)

> It has been shown that since tone has a high functional load in the [Bura] language it should not be left to the discretion of the reader, it has to be indicated in writing. (Badejo 1989:49)

> Tone has a heavier or lighter functional load according to the intensity with which it is used to make minimal distinctions of meaning. […] Even if tone has a very light functional load […] (e.g. Lingala), it is still a tone language […]. (Kutsch Lojenga 1993:5)

[4]We have been unable to locate the published version of this article; this citation appears on page 4 of a manuscript version. Unfortunately, Abena (1985) is not listed in the references.

Statements of this kind are not necessarily unhelpful. After many years of fieldwork, an experienced linguist is in a stronger position than anyone to make an informed judgment about whether tone carries a heavy or light functional load. But it should be recognized that no objective comparison between the above four statements is possible because they are only impressionistic.

Occasionally, researchers do undertake numerical counts. Burmeister (1998:2) reports that, in Anyi Sanvi (Kwa, Côte d'Ivoire), tonal minimal pairs account for 1% of the words in a lexicon of 5,000+ entries. Bird (1999a:17) states that in Komo (Bantu D, D.R. Congo), 28 lexical tonal minimal pairs were found in a list of over 3,000 words, which is 2%. But even these quantifications are not as meaningful as they might be because they are based on word lists rather than natural texts, and because the authors give no detailed indication of how the counting was done. Comparison between Anyi Sanvi and Komo would only be possible if all the researchers had adopted a standardized procedure.

2.3 Functional load and the quantification of written ambiguities We should also enumerate four ways in which our own research is distinct from most of the research on functional load. Firstly, those working on functional load are mainly concerned with oral language. Orthography developers, on the other hand, are primarily interested in written language, which in turn affects the research methodology and expected outcomes. Secondly, computational linguists tend to work on majority languages, and are therefore able to access massive, pre-existing, computerized corpuses. Those working on orthography development for minority languages such as Elip, Mbelime, and Eastern Dan, on the other hand, do not have this luxury because it can take several generations to generate a substantial body of literature. Thirdly, computational linguists tend to be concerned with evaluating the functional load of individual phonemic contrasts. That is not our concern here: The present study focuses on word-level lexical and grammatical ambiguities (cf. Unseth & Unseth 1991; Roberts 2010; 2015). This method, and experimental variations of it, has been applied successfully in numerous participatory orthography workshops across Africa (Kutsch Lojenga 1996). Fourthly, computational linguists use complex mathematical formulas that, for all their rigor and insightfulness, are far beyond the ken of most field linguists working on orthography development. Rather, what this latter group needs is a simple, standardized instrument for quantifying written tonal ambiguities if tone is not marked orthographically that they can employ when carrying out fieldwork.

3. Methodology With these concerns in mind, we adopted the following methodology for our study. Our first concern was to move beyond mere word lists and investigate written ambiguities in natural texts. We translated the four narrative texts used by Bird (1999b:111–114) into Elip, Mbelime, and Eastern Dan, employing an oral translation method to ensure naturalness that we have described in detail elsewhere

(Roberts *submitted*).[5] Each text was transcribed with and without tone marks and interlinearized.

Because of the oral translation method used, texts differ considerably in length between languages. Table 1 reports the corpus sizes in terms of number of tokens (i.e., the number of orthographic words – defined as any letter or sequence of letters flanked by spaces), and the number of types (i.e., the number of distinct orthographic word forms) for both versions of the texts. The column headed "Difference" reports the number of orthographic words that participate in tonal minimal pairs in which both members of the pair occur in the corpus, giving a first indication of the level of written ambiguity in the three orthographies if tone is not marked.

Table 1. Corpus sizes

	Tokens	Types		
		Zero tone texts	Full tone texts	Difference
ELIP	427	223	233	10
MBELIME	956	230	254	24
EASTERN DAN	743	158	219	61

Then, in each language, we drew up a list of tonal minimal pairs in the versions of the four texts that were written without tone marks.[6] For this purpose, we exploited all available resources. Three of the authors have extensive knowledge of one language each (Ginger Boyd for Elip; Johannes Merz for Mbelime; Valentin Vydrin for Eastern Dan). Published dictionaries were accessed in Mbelime (Sambiéni et al. 2004–2019) and Eastern Dan (Vydrin & Kességbeu 2008), as well as a yet unpublished lexical database and grammar sketch in Elip.[7] But the most important resource to ensure the success of the methodology is the L1 informants' own knowledge of the language. Here the challenge is that even highly trained, literate informants are unlikely to be able to detect many written ambiguities as long as words are embedded in their natural contexts. In Mbelime we experimented with a technique to avoid this problem. Each word of the text was reproduced without tone marks on a separate card. The cards were then shuffled and presented individually to two informants in turn who wrote the various meanings of the word on the card and checked each other's work. The content of each card was then discussed with the researcher and further changes and additions made where necessary.

Once the data had been elicited in the three languages, we then separated them into lexical ambiguities (e.g., *walk* vs. *sleep*), grammatical ambiguities (e.g., *he walked*

[5]In fact the texts had to be translated from English into French first, as French is the official language of Cameroon, Benin, and Côte d'Ivoire. The texts were labeled SQUIRREL, EXILE, SORCERY, and PANTHER.

[6]A reviewer expressed the concern that it must be harder to identify tonal minimal pairs on the zero tone version of a text than on the full tone version. We disagree. Presented with a tone marked word, the informant would have to imagine what it might mean if it carried other tone marks. Presented with a zero tone-marked word, on the other hand, he or she only has to imagine what tone marks it could carry in order to convey meaning.

[7]An Elip lexicon of 1,625 words has been published on Webonary: https://elip.webonary.org/.

vs. *he is walking*), and cases where the two coincide (e.g., *he walked* vs. *he is sleeping*). We discarded repeated words and polysemy. Homophones were listed as primary and secondary meanings of a single form. We also discarded pairs that could not occupy the same syntactic slot. This meant that, for example, noun/verb pairs were not reported and that the infinitive was excluded from comparison with other conjugations because it never occupies the position of the main verb. However, this stipulation was set aside in individual cases, where it could be shown that syntactic context does not adequately disambiguate, as will be the case with one set of ambiguities in Eastern Dan (see §6.3.4).

In the phonemic and phonetic transcriptions that follow, the palatal approximant /j/ is transcribed /y/ following the Africanist tradition; nasal vowels are marked with a subscript tilde /◌̰/; tone is marked with superscript diacritics: extra-high (xH) with a double acute accent /ő/, high (H) with an acute accent /ó/, mid (M) with a macron /ō/, low (L) with a grave accent /ò/, extra-low (xL) with a double grave accent /ȍ/; and contour tones on single tone bearing units with combinations of these (specifically, LH /ǒ/ in Elip, MH /ṑ/ in Mbelime, H-xL /ô/,[8] and M-xL /ṑ̏/ in Eastern Dan).

We now turn to a presentation of the results in Elip[9] (§4), Mbelime (§5), and Eastern Dan (§6). In all cases, the form and meaning that actually occurs in the text is highlighted in **bold**.

4. Elip

4.1 Language overview Elip (ISO 639-3: ekm) is a Bantu A62 language (Grollemund 2012) spoken by about 20,000 speakers in the Mbam-et-Inoubou District of the Centre Region of Cameroon. The standard orthography has only recently been developed (Boyd 2006/2015).

Elip has twenty consonant phonemes: /b, d, g, t, k, ᵐb, ⁿd, ᵑg, f, s, h, ᵐf, ⁿtʃ, m, n, ɲ, ŋ, l, y, w/ (Boyd 2015a:117). In addition to prenasalized plosives, homorganic nasal noun class prefixes are attested (124).[10] The palatal nasal /ɲ/ is written <ni> in word initial position and as <ny> elsewhere. The velar nasal /ŋ/ is written <ŋ> and the prenasalised velar stop /ᵑg/ as <ng>.

Elip has eight vocalic phonemes /i, ɪ, e, a, u, ʊ, o, ɔ/ (Boyd 2015a:119), but they are represented by only seven graphemes in the orthography <i, ɛ, e, a, u, o, ɔ>. The phoneme /ɪ/ is represented as <i> in open syllables and as <ɛ> in closed syllables and word-finally. The same patterning is true of the corresponding back vowels. These spellings are all allophonic, corresponding to the pronunciation. Conversely, since the phoneme /i/ is spelled as <i> in all positions, the phonemes /i/ and /ɪ/ are under-

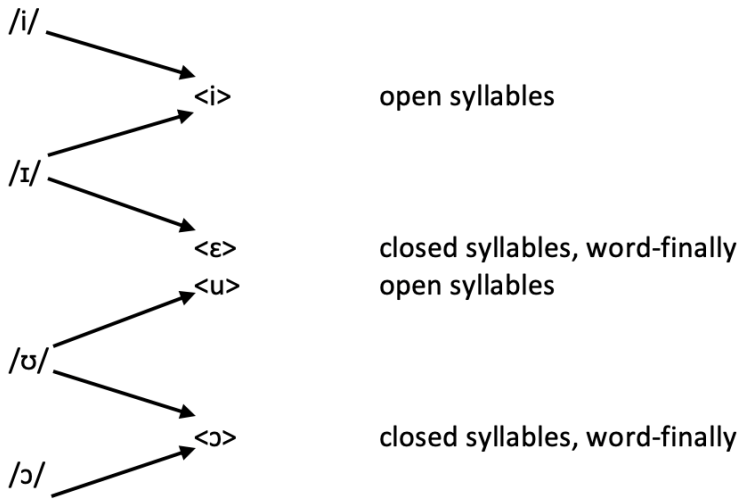
[8]The circumflex usually indicates HL in African languages, but since this pattern is unattested on single vowels in Eastern Dan, it is available for signaling H-xL.

[9]The same kind of analysis of written tonal ambiguities was carried out on the closely related languages of Mmala and Yangben with similar results to Elip.

[10]The phoneme /ⁿs/ and the sequence /n̩s/ are pronounced [ⁿtʃ] and [n̩tʃ] respectively in the Yambassa reference dialect, and as [ⁿs] and [n̩s] respectively in the Balamba and Mana-Kanya dialects. They are both spelled invariably as <ns>.

represented in open syllables, and same is true of the phoneme /ɔ/ with respect to /ʊ/. Figure 1 summarizes these phonographic relationships.

Figure 1. Over- and under-representation of vowels in Elip



Elip has two contrastive tones, H and L, automatic and non-automatic downstep, and various morphotonological processes – that is, contextual tonal changes that occur across morpheme boundaries (Boyd 2015a:134–135). Certain lexical processes such as H tone spread are represented in the orthography, but non-automatic downstep is not. This is because L1 speakers are completely unaware of the phenomenon – they consistently hear ↓H as H – and decision makers strongly resisted representing it. Post-lexical processes such as utterance-final H tone lowering and final-vowel devoicing/elision are not represented.

The orthography marks tone fully[11] by means of diacritics (an acute accent to signal H tone <◌́> and absence of an accent to signal L tone <◌>). Since vowel length is not contrastive, contour tones on single tone bearing units are written by doubling the vowel, e.g. /ǎ/ <aá>. Long vowels are (perhaps unfortunately) also written when necessary to respect the morpheme count within the conjugated verb.

4.2 Lexical tone The Elip corpus contains only one lexical tonal minimal pair, both nouns, and both meanings occur, though not in the same text (1).

(1) a. **/n^{y}ò ɲù/ <nionyi>** ***market***
b. **/n^{y}ó ɲù/ <nionyi>** ***cry (n.)***

[11]Or rather, "almost fully" because certain past tenses have a predictable floating H tone that docks onto the last TBU of the word; the decision was made to leave this tone under-represented (see example 7).

4.3 Grammatical tone The Elip texts contain 43 words, all of them verbs,[12] that participate in grammatical tonal minimal pairs, some of which are repeated. Of these, by far the most common contrast is between the narrative past and the present, of which there are 33 examples. In all cases, the correct (**bold**) interpretation in the texts is the narrative past (2)–(6).

(2) a. **/àbǎn/ <abaán>** ***they saw***
b. /àbán/ <abáán> *they are seeing*

(3) a. **/iyègìᵐbìn/ <iyegimbin>** ***it stopped***
b. /ìyěgìᵐbìn/ <iyeégimbin> *it is stopping*

(4) a. **/ʊ̌hʷʊ̌dɔ̀ŋɛ̀n/ <uhuɔ́dɔŋɛn>** ***it called***
b. /ʊ́hʷɔ́dɔ̀ŋɛ̀n/ <uhúɔ́dɔŋɛn> *it is calling*

(5) a. **/ʊ̀wǎdáb/ <uwaádáb>** ***(s)he accepted***
b. /ʊ̀wádáb/ <uwáádáb> *(s)he is accepting*

(6) a. **/ʊ̀wǎdɛ̀g/ <uwaádɛg>** ***(s)he broke***
b. /ʊ̀wádɛ̀g/ <uwáádɛg> *(s)he is breaking*

The Elip texts contain eight words that participate in tonal minimal pairs between the recent and distant past. The meanings in the texts vary between the two tenses (7)–(12).

(7) a. /báméd/ <baméɛ́d> *they left (just now)*
b. **/bámɛ̀ɛ́d/ <bamɛɛ́d>** ***they left (before yesterday)***

(8) a. **/m̀mágʷɛ̀n/ <mmáguɛn>** ***I fell (just now)***
b. /m̀mágʷɛ̀n/ <mmaguɛn> *I fell (before yesterday)*

(9) a. /ʊ̀mábá/ <umábá> *(s)he was (just now)*
b. **/ʊ̀màbá/ <umabá>** ***(s)he was (before yesterday)***

[12]Out of a total of 93 finite verbs in the texts. Only finite verbs were counted, but these include conjugated subordinate verbs and conjugated verbs in direct or indirect speech.

(10) a. /ʊ̀máb^{y}ànàn/ <umábianan> *(s)he had (just now)*
b. **/ʊ̀màb^{y}ànàn/ <umabianan>** ***(s)he had (before yesterday)***

(11) a. /ʊ̀mádìgɛ̀n/ <umádigɛn> *(s)he left (just now)*
b. **/ʊ̀màdìgɛ̀n/ <umadigɛn>** ***(s)he left (before yesterday)***

(12) a. /ʊ̀mág^{w}ɛ̀n/ <umáguɛn> *(s)he fell (just now)*
b. **/ʊ̀màg^{w}ɛ̀n/ <umaguɛn>** ***(s)he fell (before yesterday)***

The Elip texts contain one word that participates in a tonal minimal pair contrasting the distant past with the present (13), and another contrasting the near future with the distant future (14).

(13) a. /ʊ̀mà̰ɲɛ̀/ <umanyɛ> *(s)he still was (before yesterday)*
b. **/ʊ̀má̰ɲɛ̀/ <umányɛ>** ***(s)he is being***[13]

(14) a. **/ŋ̍ŋ̍ǎbʊ̀lígànɔ̀/ <ŋŋaábulíganɔ>** ***I will immediately climb***
b. /ŋ̍ŋàbʊ̀lígànɔ̀/ <ŋŋabulíganɔ> *I will climb tomorrow*

5. Mbelime

5.1 Language overview Mbelime (ISO 639-3 mql) is an Eastern Oti-Volta Gur language spoken by about 131,000 people mostly in the Atacora department of northwestern Benin (Merz 2017:10, 24). The standard orthography was first developed in 1979 (SLM 1981).

Mbelime has 14 consonant phonemes: /p, t, c, k, k͡p, b, ɖ, f, s, m, n, y, w, h/ (Neukom 2004:5). The labio-velar stop is written <kp> and the retroflex plosive /ɖ/ as <d>. It also has seven contrastive vowel phonemes /i, e, ɛ, a, u, o, ɔ/, all of which may be nasalized (Neukom 2004:7).

Mbelime has three contrastive level tones, H, M and L, contour tones, downstep, upstep, and various morphotonological processes (Liu 2013; Melick 2012). Lexical processes such as L tone spread are represented in the orthography, while postlexical ones such as upstep of successive H tones are not. In terms of orthographic depth, then, the orthography represents the output of the lexical phonology, as recommended by Snider (2014, 2018). The orthography, at the time this research was

[13] This may be a case of a recent past verb which is best rendered in English as present continuous.

conducted, marked H tone with an acute accent /◌́/, M tone with a macron /◌̄/, and L tone with absence of an accent /◌/.[14] Contour tones are under-represented.

5.2 Lexical tone

5.2.1 Nouns The Mbelime texts contain eleven nouns[15] that participate in lexical tonal minimal pairs (15).

(15)	a.	**/bɛ̄ hɔ̰̄pɛ̀/**	**<bɛ̄ hɔ̰́pɛ>**	***witches***	/bɛ̄ hɔ̰̀pɛ̀/	<bɛ̄ hɔ̰pɛ>	*initiation sponsor*
	b.	**/kɛ̄ būɔ̄kɛ̀/**	**<kɛ̄ būɔ̄kɛ>**	***dog***	/kɛ̄ bùɔ̀kɛ̀/	<kɛ̄ buɔkɛ>	*weak heart*
	c.	**/kɛ̄ nīn̄kɛ̀/**	**<kɛ̄ nīn̄kɛ>**	***thing***	/kɛ̄ nìǹkɛ̀/	<kɛ̄ ninkɛ>	*meat*
	d.	**/ū kùɔ̀hṳ̀/**	**<ū kuɔhṳ>**	***bag***	/ū kúɔ́hṳ̀/	<ū kúɔ́hṳ>	*trunk*
	e.	**/ī hḭ̄ǹnī/**	**<ī hḭ̄nnī>**	***inside***	/ī hḭ́ńní/	<ī hḭ́ńní>	*sky*

The last example in this set deserves special attention because when the two words appear without class prefixes their meanings are *in* and *on* respectively, and the four meanings together have a highly unbalanced distribution in the corpus: <hḭ̄nnī> 'in' (12 times), <ī hḭ̄nnī> 'inside' (4), <hḭ́ńní> 'on' (1), <ī hḭ́ńní> 'sky' (0). We will return to the question of how to assess such imbalances in a discussion on methodology refinement (§8.1).

5.2.2 Verbs The Mbelime texts contain eight verbs that participate in lexical tonal minimal pairs (16).

(16)	a.	**/tóńtá/**	**<tóńtá>**	***arrive (NEU)***	/tōn̄tá/	<tōn̄tá>	*unbutton (NEU)*
	b.	**/cɔ̄ɔ̄tɔ̀/**	**<cɔ̄ɔ̄tɔ>**	***take girl as wife (PRF)***	/cɔ́ɔ́tɔ̀/	<cɔ́ɔ́tɔ>	*calcify (PRF)*
	c.	**/kuutá/**	**<kuutá>**	***go back into (IPF)***	/kūùtā/	<kūutā>	*pound badly (IPF)*
	d.	**/yōòtā/**	**<yōotā>**	***raise hand (NEU)***	/yōōtá/	<yōōtá>	*speak (NEU)*

The Mbelime texts contain six verbs that participate in lexical tonal minimal triplets (17)–(18).

(17)	a.	**/būūní/**	**<būūní>**	***judge (NEU)*** [16]
	b.	/būùnī/	<būunī>	*grind badly (NEU)*
	c.	/búúní/	<búúní>	*brew (NEU)*

[14]The data in this article is transcribed using the orthography that was in use when the research was conducted. Since then, there has been a spelling reform. See §8.3 for further details.

[15]In the course of this analysis, we found five words in the Mbelime texts in which class prefixes had been written joined to the noun root. Since this was incorrect spelling at the time of the experiment (it is another aspect of the 2017 reform), we excluded these from the list of tonal minimal pairs.

[16]In Mbelime, the neutral aspect is used to express both the imperative and the future.

(18) a. **/tóńtɔ̀/ <tóńtɔ>** ***arrive (PRF)***
b. /tòǹtɔ̀/ <tontɔ> *hurry (PRF)*
c. /tōn̄tɔ̀/ <tōn̄tɔ> *unbutton (PRF)*

5.3 Grammatical tone The Mbelime texts contain six verbs that participate in grammatical tonal minimal pairs between the neutral on the one hand and the perfective (19a–c), the imperfective (19d), or the habitual (19e) on the other. In two cases, (19a) and (19e), both meanings appear in the texts.

(19)

a. **/pōō/**	**<pōō>**	***kill (NEU)***	**/póò/**	**<póo>**[17]	***kill (PRF)***
b. **/hīī/**	**<hīī>**	***die (NEU)***	/hîì/	<híi>	*die (PRF)*
c. **/tōō/**	**<tōō>**	***bring (NEU)***	/tóò/	<tóo>	*bring (PRF)*
d. **/hūùsì/**	**<huusi>**	***shout (NEU)***	**/húúsí/**[18]	**<húúsí>**	***shout (IPF)***
e. **/yīènì/**	**<yīeni>**	***accept (NEU)***	/yíéní/	<yíéní>	*accept (HAB)*

The Mbelime texts contain one verb that participates in a grammatical tonal minimal triplet between the neutral, the imperfective and the habitual (20). Two of the three meanings occur in the texts.

(20) a. **/pēdìmù/ <pēdimu>** ***explain (NEU)***
b. **/pédímú/ <pédímú>** ***explain (HAB)***
c. /pèdìmú/ <pedimú> *explain (IPF)*

5.4 Lexical and grammatical tone The Mbelime texts contain five words that participate in tonal minimal pairs in which lexical and grammatical tone coincide (21)–(22).

(21) a. **/bàsí/ <basí>** ***choose (IPF)***
b. /bāsī/ <bāsi> *meet (NEU)*

(22) a. **/tɛ̄/ <tɛ̄>** ***belong to (PRF)***
b. /tɛ̀/ <tɛ> *be nasty (PRF, HAB, NEU)*

[17]This meaning occurs twice in consecutive sentences in the SORCERY text. In the first occurrence, it is spelled incorrectly as <póó>.
[18]Our Mbelime informant considers <huusí> [hùùsí] to also be an acceptable spelling and pronunciation for this meaning.

The Mbelime texts contain eleven words that participate in tonal minimal triplets in which lexical and grammatical tone coincide (23)–(24).

(23) a. **/hīī/ <hīī> *die (NEU)***
b. /híì/ <híi> *die (PRF)*
c. /hīī/ <hīī> *stare (NEU, PRF, IPF)*

(24) a. **/hōǹsī/ <hōnsī> *fight (IPF, NEU)***
b. /hōñsí/ <hōñsí> *dry quickly (NEU, IPF)*
c. /hóńsí/ <hóńsí> *be greedy (PRF)*

6. Eastern Dan

6.1 Language overview Eastern Dan (ISO 639-3 dnj) is a South Mande language spoken by about 650,000 people in and around the town of Man in the Montagnes district of Côte d'Ivoire (Eberhard et al. 2019). The orthography that was being used at the time of our research was standardised in 1982.[19]

Eastern Dan has 17 consonant phonemes /p, t, k, kp, b, d, g, gb, f, s, v, z, ɓ, ɗ, l, y, w/ (SIL 1982:4; Vydrin & Kességbeu 2008:9–10). In the 1982 orthography, the phonemes /ɓ, ɗ/ are pronounced and spelled [m, n] <m, n> preceding a nasal vowel and [ɓ, ɗ] <bh, dh> elsewhere, respectively. The phoneme /l/ is pronounced [ɾ] and spelled <r> following a coronal consonant, and [l] elsewhere.

Eastern Dan has twelve oral vowels /i, e, ɛ, æ, ɯ, ɤ, ʌ, a, u, o, ɔ, ɒ/. In the 1982 orthography, the phonemes /ɯ, ʌ, æ, ɒ/ are written <ü, ë, ɛa, aɔ> respectively. The phonemes /e, o, ɤ/ are pronounced [ɪ, ʊ, ɣ[20]] and written <ɪ, ʊ, ö> on a xH tone syllable, and [e, o, ɤ] <e, o, ö> elsewhere, respectively.[21] There are nine nasal vowels /ḭ, ɛ̰, æ̰, ɯ̰, ʌ̰, a̰, ṵ, ɔ̰, ɒ̰/ spelled <in, ɛn, ɛan, ün, ën, an, un, ɔn, aɔn>. All of the vowels – oral and nasal – can appear in a sequence of two identical vowels. In addition, the velar nasal /ŋ/ is also best interpreted as a vowel, because it occurs in the same phonotactic slot as vowels and bears tone as vowels do (SIL 1982:8; Vydrin & Kességbeu 2008:7–9).

The 1982 orthography uses punctuation symbols placed word-initially and word-finally to signal tone. It has five phonemic level tones (xH /ő/ <''○>, H /ó/ <'○>, M /ō/ <○>, L /ò/ <=○>, xL /ȍ/ <-○>), four falling contours (xH-xL /ő̏/ <''○○->, H-xL /ó̏/ <'○○->, M-xL /ō̏/ <○○->, L-xL /ò̏/ <=○○->), and two rising contours (M-H /ṓ/ <○○'>, H-xH /ō̋/ <○○''>). Occasionally contour tones occur on single short vowels. There is a limited amount of under-representation of longer words, since the

[19]The data in this article is transcribed following the 1982 orthography, but recently there has been a spelling reform. See §8.3 for further details.

[20]Following Vydrin & Kességbeu (2008:7), we use this symbol to indicate a near-close near-back unrounded vowel.

[21]This allophony is contrastive in some dialects.

punctuation strategy cannot mark tone word-medially.[22] Eastern Dan has practically no morphotonological processes (SIL 1982:12–13; Bolli 1989; Vydrin & Kességbeu 2008:10–11).

6.2 Lexical tone

6.2.1 Nouns The Eastern Dan texts contain twelve nouns that participate in lexical tonal minimal pairs (25); four nouns that participate in lexical tonal minimal triplets (26); one noun that participates in a lexical tonal minimal quadruplet (27); and one noun that participates in a lexical tonal minimal quintuplet (28). In the latter case, two of the five meanings occur in the texts. Notice that this set – and all of the following ones – also contains numerous homophones indicated in the glosses by numbering. Thus, even though tone is written fully, the degree of written ambiguity remains relatively high.[23]

(25) a. /gbēŋ/ <gbeng> *night*
b. **/gbȅŋ/ <-gbeng>** ***1. fire-footed rope squirrel (Funisciurus pyrropus)***
2. ramification

(26) a. **/kpɒ̋ɒ̋/ <ˈˈkpaɔ>** ***travel bag***
b. /kpɒ̄ɒ̄/ <kpaɔ> *mockery*
c. /kpɒ̏ɒ̏/ <-kpaɔ> *errand*

(27) a. /gɔ̋/ <ˈˈgɔ> *panther (Panthera pardus)*[24]
b. /gɔ̄/ <gɔ> *1. tree sp. (Cordia platythyrsa) 2. palm frond 3. vehicle*
c. **/gɔ̏/ <-gɔ>** ***head***
d. /gɔ̂/ <ˈgɔ-> *cola*

[22]The 1982 orthography marks tone word-finally only on single-foot words, (e.g., /gwãã̋/ <gwëë”> ‘Nile crocodile’). On words of two or more feet, the final tone is not marked, even though in principle it could be (e.g., /fáŋ̀kpɛ̋ɛ̋/ <’fangkpɛɛ> ‘Black-and-white tailed hornbill’).

[23]We also counted tonal minimal pairs in the current version of the dictionary database, which by now contains about 25% more entries than the published version (Vydrin & Kességbeu 2008). Among the 1,858 lexical noun forms – the vast majority of which are monosyllabic – we found 143 pairs, 41 triplets, 8 quadruplets, and 2 quintuplets. This count does not include numerous cross-category pairs for the reasons stated in §3.

[24]“Panther” is the principal character in the PANTHER text, but it is the more common synonym /gwēē/ <gwee> that is used.

(28) a. /kwɛ̋ɛ̋/ <ˈˈkwɛɛ> *door*
b. /kwɛ̄ɛ̄/ <kwɛɛ> *part of a loom*
c. **/kwɛ̏ɛ̏/ <-kwɛɛ> *old man***
d. **/kwɛ̄ɛ̋/ <kwɛɛˈˈ> *hand***
e. /kwɛ̀ɛ̏/ <=kwɛɛ-> *load*

6.2.2 Verbs The Eastern Dan texts contain no verbal tonal minimal pairs that are purely lexical. All tonally ambiguous verbs contain complex interactions between lexical and grammatical tone (see §6.3.2).[25]

6.3 Grammatical tone

6.3.1 Nouns (case markers and pronouns) The Eastern Dan texts contain two nouns that participate in grammatical tonal minimal pairs (29) and triplets (30) where the isolation form contrasts with the head marked and/or the relativized form. In example (30), all three meanings occur in the texts.

(29) a. **/gbő/ <ˈˈgbo> *crying***
b. /gbȍ/ <-gbo> *crying (+ head marker)*

(30) a. **/ɓɛ̰̄/ <mɛ> *human***
b. **/ɓɛ̰̏/ <-mɛ> *human (+ head marker)***[26]
c. **/ɓɛ̰́/ <ˈmɛ> *human (+ relativization marker)***

The Eastern Dan texts contain a noun (31) and a reciprocal pronoun (32) that participate in grammatical tonal minimal pairs where the superessive case form contrasts with the isolation form or the comitative case form.

(31) a. **/kwɛ̄ɛ̋/ <kwɛɛˈˈ> *hand***
b. /kwɛ̀ɛ̏/ <=kwɛɛ-> *hand (superessive case)*

(32) a. **/kwʌ̋ʌ̋/ <ˈˈkwëë> *each other (comitative case)***
b. /kwʌ́ʌ̏/ <ˈkwëë-> *each other (superessive case)*

[25] Among the 319 lexical verb forms in the current version of the dictionary database, we found 20 pairs and 1 triplet. The current database includes forms with preverbs (separable quasi-prefixes), such as /dɪ̋ɤ-pā/ <ˈˈdhiö pa> 'to complete' and /tȁ-kpā/ <-ta kpa> 'to stick up', which are systematically written disjunctively in the 1982 orthography.

[26] This form is usually written conjunctively with the preceding word, and thus, according to the 1982 spelling rules, its tone is unmarked.

6.3.2 Verbs Eastern Dan has three tonally inflected conjugated forms (infinitive, neutral and conjoint) plus the lexical form. The lexical, neutral, and conjoint forms share the same syntactic slot. The Eastern Dan texts contain six verbs that participate in grammatical tonal minimal triplets in which the lexical, neutral,[27] and conjoint aspects contrast (33). In two cases, all three conjugations appear in the text.

(33)

	LEXICAL		NEUTRAL		CONJOINT		
a.	**/ɗó/**	**<ˈdho>**	**/ɗò/**	**<-dho>**	**/ɗō/**	**<dho>**	***go***
b.	**/gó/**	**<ˈgo>**	/gȍ/	<-go>	**/gō/**	**<go>**	***1. go away 2. sell***
c.	/kṵ̋/	<ˈkun>	/kṵ̏/	<-kun>	**/kṵ̄/**	**<kun>**	***catch***
d.	**/ɓɔ̰̄ɔ̰̏/**	**<mɔɔ->**	/ɓɔ̰̏ɔ̰̏/	<-mɔɔ>	/ɓɔ̰̀ɔ̰̀/	<=mɔɔ>	***search***
e.	**/sɯ́/**	**<ˈsü>**	/sɯ̏/	<-sü>	**/sɯ̄/**	**<sü>**	***take***
f.	**/tó/**	**<ˈto>**	**/tȍ/**	**<-to>**	**/tō/**	**<to>**	*remain*

In all of the examples in this list, the infinitive also contrasts with the neutral and conjoint, making tonal minimal triplets, and additional contrasts including the infinitive would expand the list to ten. However, the infinitive was excluded from the analysis on the grounds that it does not occupy the same syntactic slot as the other conjugations in the triplet. A further 18 words that participate in tonal minimal pairs between the infinitive and the neutral were excluded for the same reason.

The Eastern Dan texts contain many verbs in which lexical and grammatical tone coincide. Four words participate in tonal minimal pairs (34); two words participate in tonal minimal triplets (35); and one word participates in a tonal minimal quintuplet (36). In two cases (34)–(35), both lexical meanings occur in the texts. Again, if the infinitive were included in the analysis, this list would expand considerably.

(34) a. **/pɤ̄/ <pö>** ***say*** *(LEX, CJT)*
b. **/pɤ̏/ <-pö>** ***fall*** *(LEX, NEU, CJT)*

(35) a. **/ɓɔ̰̄ɔ̰̏/ <mɔɔ->** ***search*** *(LEX)*
b. **/ɓɔ̰̀ɔ̰̀/ <=mɔɔ>** ***1. be able, reach*** *(LEX, CJT) 2. search (CJT)*
c. /ɓɔ̰̏ɔ̰̏/ <-mɔɔ> *1. be able, reach (NEU) 2. search (NEU)*

(36) a. **/ɓā̰/ <ma>** ***1. hear*** *(LEX, CJT) 2. cook (LEX)*
b. /ɓá̰/ <ˈma> *appear (LEX)*
c. /ɓȁ̰/ <-ma> *beat (LEX, INF)*
d. /ɓâ̰/ <ˈma-> *appear (INF)*
e. /ɓā̰ˇ/ <ma-> *1. hear (INF) 2. cook (INF)*

[27] In Eastern Dan, the neutral aspect is a default construction expressing numerous TAM meanings (habitual, stative perfect, progressive, imperfect, resultative, and completive).

6.3.3 Predicative markers Verb conjugations are also distinguished by the forms of the pronominal predicative markers, of which each has its own series and many of which are distinguished uniquely by tone. The Eastern Dan texts contain seven predicative markers that participate in grammatical tonal minimal pairs (37)–(38) and eight that participate in grammatical tonal minimal triplets (39)–(40).

(37) a. **/ɓáá/ <ˈbhaa>** ***1. 2SG NEG IPF 2. certain + 3SG NEG PRF***
b. /ɓāà/ <bhaa-> *2SG presumptive*

(38) a. **/wàà/ <-waa>** ***3PL PRF predicative marker + 3SG non-subject pronoun***
b. **/wáá/ <ˈwaa>** ***3PL NEG IPF predicative marker***

(39) a. **/wáá/ <ˈwaa>** ***3PL NEG IPF***
b. **/wàà/ <-waa>** ***3PL subjunctive + 3SG non-subject pronoun***
c. /wāà/ <waa> *3PL presumptive*

(40) a. **/yáá/ <ˈyaa>** ***1. 3SG NEG IPF*** *2. CNJ + 1SG CJT 3. 1PL EXC NEG IPF*
b. **/yàà/ <=yaa->** ***3SG PRF + 3SG non-subject pronoun***
c. /yāà/ <yaa-> *1. 3SG presumptive 2. 1PL EXC presumptive*

6.3.4 Other parts of speech This leaves a miscellany of six words from other parts of speech that participate in tonal minimal pairs (41)–(46). In two cases, two of the various meanings occur in the text.

(41) a. **/ɓá/ <ˈbha>** ***certain, one***
b. **/ɓā/ <bha>** ***1. definite article*** *2. equative copula 3. there (near the listener)*

(42) a. **/kó/ <ˈko>** ***each other***
b. /kō/ <ko> *1. 1PL.DUAL.INC autonomous pronoun*
2. 1PL.DUAL.INC non-subject pronoun

(43) a. **/klɤ̄ɤ̀/ <klöö->** ***short***
b. /klɤ̄ɤ̋/ <klöö'> *short (intensive)*

(44) a. **/sīʌ̄/ <sië->** ***durative marker***
b. /sìʌ̀/ <=sië> *sometimes; often*

(45) a. **/yɤ́/ <ˈyö>** ***consecutive conjunction***
b. **/yɤ̂/ <ˈyö->** ***consecutive conjunction + 3SG non-subject pronoun***

(46) a. **/zɯ́/ <ˈzü>** ***any more, more***
b. /zɯ̀/ <-zü> *around*

6.3.5 Outstanding pairs Finally, we need to admit that many ambiguities in the Eastern Dan texts defy easy categorization because the functional load of tone is so extraordinarily heavy. All of the pairs and triplets in examples (41)–(46) contain items that belong to different parts of speech, yet they can still occupy positions where they can easily be misinterpreted, especially by non-fluent readers. For example, the eight nominal meanings of the word <gban> (47) would fit neatly into the analysis above, except that, as it happens, none of them appear in the texts. The meaning that does occur is the determiner 'all, entire' which automatically excludes the entire set from the analysis on the grounds that nouns and determiners do not share the same syntactic slot.

(47)

a.	**/gbà/**	**<=gban>**	***all, entire***	**DETERMINER**
b.	/gbɑ̰̋/	<ˈˈgban>	*leg*	NOUN
c.	/gbɑ̰̄/	<gban>	*wing, shoulder*	NOUN
d.	/gbɑ̰̀/	<gban>	*1. ceiling*	NOUN
			2. pressure	
e.	/gbɑ̰̏/	<-gban>	*support*	NOUN
f.	/gbɑ̰̂/	<ˈgban->	*1. tree sp. (Ricinus communis)*	NOUN
			2. black ants	
			3. curse	
			4. uproar	

But this procedure for systematising the data overlooks the fact that the word <gban> may well be mistaken for a noun or a determiner when the two occupy the same position in a sentence, for example in (48).

(48)

a.	/ȁ gbā tɔ̏ gbą̋ ká/ 3SG.NSBJ give chicken leg with	<-a gba -tɔ ˈˈgban ˈka>	*give him a chicken leg*
b.	/ȁ gbā tɔ̏ gbą̄ ká/ 3SG.NSBJ give chicken wing with	<-a gba -tɔ gban ˈka>	*give him a chicken wing*
c.	/ȁ gbā tɔ̏ gbą̀ ká/ 3SG.NSBJ give chicken all with	<-a gba -tɔ =gban ˈka>	*give him all the chickens*[28]

Similar ambiguities are possible in the following five tonal minimal pairs and triplets (49)–(53).

(49) a. **/ɗ̀ʌ̰/ <në>** ***focalization marker*** **PARTICLE**
b. /ɗʌ̰́/ <ˈnë> *child* NOUN

(50) a. **/pɤ̏/ <-pö>** ***fall (LEX, NEU, CJT)*** **VERB**
b. /pɤ́/ <ˈpö> *also* ADVERB

(51) a. **/sɯ́/ <ˈsü>** ***take (LEX)*** **VERB**
b. **/sɯ̏/ <-sü>** ***1. gerund marker*** *2. take (NEU)* **1. PARTICLE** 2. VERB
c. /sɯ/ <sü> *take (CJT)* VERB

(52) a. **/tȁ/ <-ta>** ***1. on, upon*** *2. close, shut (NEU)* **PREPOSITION**, VERB
b. /tā/ <ta> *close, shut (LEX, CJT)* VERB

(53) a. **/wɛ̋ɛ̋/ <ˈˈwɛɛ>** ***1. other*** *2. in vain* **1. DETERMINER** 2. ADVERB
b. /wɛ̏ɛ̏/ <-wɛɛ> *sleeping place* NOUN

7. Quantifying the ambiguities We are now in a position to attempt a simple quantification of tonal ambiguities if tone were not marked orthographically in the three languages. In Tables 2–5 below, for each language, the left-hand column reports the raw number of ambiguous words detected. Then in the right hand column, to account for all possible contrasts (Schroeder 2008:56; Chen et al. 2009; Huff & Payne 2012), tonal minimal triplets are multiplied by three (because there are three possible pairs: AB, AC, BC); quadruplets by six (AB, AC, AD, BC, BD, CD); quintuplets

[28]The plural marker <*–nu*> [ɓṵ̀] is absent when a noun is followed by the determiner <=*gban*> [gbą̀] 'all, entire'.

by ten (AB, AC, AD, AE, BC, BD, BE, CD, CE, DE); and, in one case, a sextuplet by fifteen (AB, AC, AD, AE, AF, BC, BD, BE, BF, CD, CE, CF, DE, DF, EF). The raw totals are the sums of the sub-totals. The latter is then divided by the corpus size – which varies considerably between languages because of the oral translation method used – to attain a percentage.

Table 2 presents a summary of the lexical tonal ambiguities if tone is not marked orthographically in the three languages. These are verging on non-existent in the Elip texts, whereas Mbelime has many, especially among verbs. As for Eastern Dan, although the overall score is higher than the other two languages, pure lexical tone is concentrated in the nouns, and completely absent among verbs.

Table 2. Lexical tonal ambiguities in the Elip, Mbelime, and Eastern Dan texts

	ELIP		**MBELIME**		**E. DAN**	
Lexical tone (nouns)						
Pairs (x 1)	1	1	11	11	12	12
Triplets (x 3)	0	0	0	0	4	12
Quadruplets (x 6)	0	0	0	0	1	6
Quintuplets (x 10)	0	0	0	0	1	10
Sub-total		1		11		40
Lexical tone (verbs)						
Pairs (x 1)	0	0	8	8	0	0
Triplets (x 3)	0	0	6	18	0	0
Sub-total		0		26		0
Raw total		1		37		40
Corpus size		427		956		743
% Total		0.23%		3.87%		5.38%

Table 3 summarizes the grammatical tonal ambiguities if tone is not marked orthographically. All three languages attest grammatical tone among verbs, but this is not where the tonal ambiguities in Mbelime come to the fore, in spite of having triplets as well as pairs. Elip and Eastern Dan have similar scores on grammatical tone. In spite of Elip having no groupings larger than pairs, it has a few verb conjugations that are frequent in narrative texts. Eastern Dan, on the other hand, is the only language to have (limited) grammatical tone on nouns, and in which categories other than nouns and verbs are needed when cataloguing grammatical tone, including predicative markers, other parts of speech, and a separate statement covering pairs that are ambiguous in spite of not sharing the same syntactic slot. This latter category contains the only sextuplet in the whole analysis.

Table 3. Grammatical tonal ambiguities in the Elip, Mbelime, and Eastern Dan texts

	ELIP		MBELIME		E. DAN	
Grammatical tone (case markers and pronouns)						
Pairs (x 1)	0	0	0	0	3	3
Triplets (x 3)	0	0	0	0	1	3
Sub-total		**0**		**0**		**6**
Grammatical tone (verbs)						
Pairs (x 1)	43	43	6	6	0	0
Triplets (x 3)	0	0	1	3	6	18
Sub-total		**43**		**9**		**18**
Grammatical tone (predicative markers)						
Pairs (x 1)	0	0	0	0	7	7
Triplets (x 3)	0	0	0	0	8	24
Sub-total		**0**		**0**		**31**
Grammatical tone (other parts of speech)						
Pairs (x 1)	0	0	0	0	6	6
Sub-total		**0**		**0**		**6**
Grammatical tone (outstanding pairs)						
Pairs (x 1)	0	0	0	0	4	4
Triplets (x 3)	0	0	0	0	1	3
Sextuplets (x 15)	0	0	0	0	1	15
Sub-total		**0**		**0**		**22**
Raw total		**43**		**9**		**83**
Corpus size		**427**		**956**		**743**
% TOTAL		**10.07%**		**0.94%**		**11.17%**

Table 4 summarizes the ambiguities in which lexical and grammatical ambiguities coincide. Elip scores zero in this category because it has no lexical pairs among verbs. Mbelime, on the other hand, has a good deal of interplay between lexical and grammatical tone scoring higher than Eastern Dan on this measure, in spite of the latter language boasting one quintuplet.

Table 4. Ambiguities in which lexical and grammatical tone coincide in the Elip, Mbelime, and Eastern Dan texts

	ELIP		MBELIME		E DAN	
Lexical and grammatical tone (verbs)						
Pairs (x 1)	0	0	5	5	4	4
Triplets (x 3)	0	0	11	33	2	6
Quintuplets (x 10)	0	0	0	0	1	10
Raw total		**0**		**38**		**20**
Corpus size		**427**		**956**		**743**
% TOTAL		**0.00%**		**3.97%**		**2.69%**

Table 5 summarizes the level of written ambiguity in the three languages if tone is not marked in the orthographies, combining scores for lexical tone, grammatical tone, and cases where lexical and grammatical tone coincide. Elip and Mbelime have similar scores, but both are eclipsed by Eastern Dan.

Table 5. Summary of written ambiguities in Elip, Mbelime, and Eastern Dan if tone is not fully marked

	ELIP	MBELIME	E DAN
Lexical tone	0.23%	3.87%	5.38%
Grammatical tone	10.07%	0.94%	11.17%
Lexical and grammatical tone	0.00%	3.97%	2.69%
TOTAL	**10.30%**	**8.78%**	**19.24%**

8. Discussion

8.1 Refining the methodology The methodology proposed in this paper might benefit from further refinement in several respects. Our main concern is that the corpuses are not large or varied enough for an exhaustive analysis. The Mbelime corpus is inevitably more reliable than the Elip corpus merely by virtue of being over twice the size. Of the 471 verbs in the Elip lexical database, 22 (4.7%) are tonal minimal pairs, so it is likely that an analysis of a larger text corpus might reveal results quite different from those presented above. Roberts (2010:29), for example, needed a corpus of

over 142,000 words and containing a wide range of text genres to capture the most infrequent cases of grammatical tone in Kabiye.

Should all ambiguities be given equal weight? Our analysis overlooks the strong likelihood that grammatical ambiguities, by their very nature, are often more easily confusable in context than lexical ones. It may also be desirable to assign greater weight to tonal ambiguities in which both words occur in the text than to those in which only one of the pair occurs. Then, in the former case, pairs that appear in the same visual field are surely more ambiguous than those that are distant from each other. Faced with data such as the last item in Mbelime example (15), with its highly unbalanced distribution of meanings, it may also be wise to take into account Kadyamusuma & Kadenge's (2013:88) distinction between balanced homographs, (i.e., those with two equally frequent meanings) and biased homographs (i.e., those with one meaning that is more frequent).

Furthermore, while our analysis takes syntactic context into account, it ignores the much greater challenge of quantifying the contribution of semantic context. In Elip, the simple past is often the obvious semantic choice once the reader has recognized the narrative nature of the texts, e.g., examples (2)–(6). In Mbelime, the lexical pair 'bag' vs. 'trunk' (15d) is much more semantically confusable than 'dog' vs. 'weak heart' (15b).

A reviewer has questioned whether the study paid enough attention to morpho-tonological processes, given that, depending on how they are written, they may blur the distinction between lexical and grammatical tone. We investigated this point with respect to lexical L tone spread in Mbelime but found no evidence that it leads to ambiguity. This is because the full tone version of the orthography represents the output of the Lexical Phonology – correctly, we believe – and leaves surface post-lexical processes unrepresented.

As another reviewer has noted, high-frequency ambiguities such as pronominal tonal minimal pairs may impact reading fluency at several points in one text, so perhaps it is not advisable to discard repeated words. This is a valid point, although it would be necessary to control for the fact that oral reading errors of any difficult words, not just tonal minimal pairs, tend to decline with repeated occurrences within a single text, as demonstrated in Eastern Dan (Roberts & Vydrin 2019) and Kabiye (Roberts 2008:360–361).

Yet another concern is whether it is acceptable to compare written ambiguities between languages that have differing levels of resources to help identify them. One informant may be particularly adept at spotting potential ambiguities, while another needs more training and supervision. One researcher may have an extensive knowledge of the language structure, making it possible to suggest hypothetical ambiguities to an informant, while another has little or no such knowledge. One language may be well documented, while another is under-documented. At the very least, such variables need to be admitted when the proposed methodology is applied cross-linguistically.

Doubtless all of these issues leave room for improvement. However, we have a lingering concern that, if future researchers end up cherry picking from the discus-

sion points above, the domain will continue to be hampered by non-standardized methodologies, and paradoxically this article will have failed in its primary purpose.

8.2 Additional experimental data The data presented in this paper emerge from a wider research project testing reading and writing fluency in ten Niger-Congo languages. In an experiment design modeled on Bird (1999b), 308 participants orally read unmarked and marked versions of the same four translated narrative texts.

Tellingly, the experiment results show no statistically significant evidence of the need to mark tone fully in Elip, and only patchy evidence in Mbelime and Eastern Dan. The presence or absence of full tone marking does not contribute to oral reading speed in any of these three languages, neither does it enhance accuracy in Elip. It may, cautiously, increase tonal accuracy in Mbelime (by 43.46%, $p = 0.090$) and general accuracy in Eastern Dan (by 18.95%, $p = 0.094$), and it definitely improves comprehension in Mbelime (by 13.90%, $p = 0.036$). As for the supplementary task of adding tone marks to unmarked texts, scores are pitifully low in Elip (30.15% mean success rate), and far from spectacular in Mbelime (68.69%) and Eastern Dan (61.11%). For a fuller report, see Roberts (submitted).

8.3 Spelling reform Orthography stakeholders in all three languages have also been involved in a lengthy process of spelling reform spanning the period of the research project. In Elip, they have recently veered towards a surface-tone marking system at the cost of consistent word images, apparently motivated by a concern for the needs of non-L1 speakers.[29] In Mbelime, decision makers recently aligned themselves with Beninese government recommendations (CENALA 2011) by reversing two of the tone marks. From now on, L tone will be marked with a grave accent and M tone will be unmarked (CNLM 2017:9; Merz et al. 2017:11; see Appendix, Figure 6). As for Eastern Dan, decision makers have recently adopted a radical spelling reform that employs superscript diacritics for marking tone, biunique segmental correspondence, and special characters for marking vowels (Roberts et al. 2019; Vydrin et al. 2019; see Appendix, Figure 9).

In all three languages, then, full tone marking has survived recent spelling reforms. None of them, at this stage in their development, is investigating other possibilities such as the partial marking of grammatical tone (Kutsch Lojenga 1993), or zero marking for fluent readers, following the precedent of Hebrew vowel pointing (Frost & Bentin 1992).

9. Conclusion In closing, let us return to the proposed methodology for quantifying tonal ambiguities. We firmly align ourselves with the view that it would be undesirable to set up a mechanical, numerical threshold above which tone must be marked fully in an orthography (Gordon 1986:76; Unseth & Unseth 1991:46). Nevertheless,

[29]We have not reproduced the reformed Elip orthography in the Appendix because we are unsure of the exact nature of the changes.

we offer this methodology as a tool for orthography developers seeking a standardized, simple procedure for measuring written ambiguities if tone is not marked in a tone language. It will also provide a promising basis for any researcher wishing to develop a quantitative typology of tone systems based on the functional load of tone in the lexicon and the grammar. For whatever purpose it is employed, we hope to have also shown that there is nothing dishonorable about evaluating the functional load of tone – recalling King's definition with which we began this article – "in its simplest expression".

Abbreviations

CJT	conjoint
CNJ	conjunction
EXC	exclusive
H	high tone
HAB	habitual
INC	inclusive
INF	infinitive
IPF	imperfective
L	low tone
LEX	lexical
M	mid tone
n.	noun
NEU	neutral
NEG	negative
Nsbj	non-subject series of personal pronouns
PL	plural
PRF	perfective
SG	singular
xH	extra-high tone
xL	extra-low tone

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Appendix. Text samples

Figures 2–9 show the first paragraph of the SQUIRREL text in the three languages with full tone marking, zero tone marking, and, where appropriate, the recent spelling reforms.

Elip

Figure 2. ELIP written with full tone marking (2015 orthography)

Na Ombóge na Mbuá bamɛɛ́d gá guében ikumb. Bamaábaándá Ombóge uganyɛ gá Mbuá áneé: ‹‹Yaŋuá ŋŋaábulíganɔ uguá bukumb gá giagiá yaŋuá nnyɛ mɔnɔ́ nuɔ́l.»

Figure 3. ELIP written with zero tone marking

Na Omboge na Mbua bamɛɛd ga gueben ikumb. Bamaabaanda Omboge uganyɛ ga Mbua anee: ‹‹Yaŋua ŋŋaabuliganɔ ugua bukumb ga giagia yaŋua nnyɛ mɔnɔ nuɔl.»

Mbelime

Figure 4. MBELIME written with full tone marking (1999 orthography)

Kɛ̄ kɔ̄ɔkɛ nnɛ kɛ̄ būɔ̄kɛ yɛ̄ dɛ̄ɛ biití n nɔ̄ɔ̄sī ā būɔnɛ ā fɛ̄. Dāāde bā ā ń bō a kɛ̄ kɔ̄ɔkɛ nnɛ kɛ̄ būɔ̄kɛ ā yɛ̱ : « Tī bɔ̄kī n yūutā nkaā ū tēwuɔhụ̱ hḭ̱nnī. »

Figure 5. MBELIME written with zero tone marking

Kɛ kɔɔkɛ nnɛ kɛ buɔkɛ yɛ dɛɛ biiti n nɔɔsi a buɔnɛ a fɛ. Daade ba a n bo a kɛ kɔɔkɛ nnɛ kɛ buɔkɛ a yɛ̱ : « Ti bɔki n yuuta nkaa u tewuɔhụ̱ hḭ̱nni. »

Figure 6. MBELIME written with full tone marking (2017 orthography)

Kɛkɔɔ̀kɛ̀ ǹnɛ̀ kɛbuɔkɛ̀ yɛ dɛɛ̀ bììtí ǹ nɔɔsi abuɔ̀nɛ̀ a fɛ. Daadè ba a ń bo à kɛkɔɔ̀kɛ̀ ǹnɛ̀ kɛbuɔkɛ̀ a yɛ̰ : « Ti bɔki ǹ yuùta ǹkàa utewùɔ̀hṳ̀ hḭǹni. »

Eastern Dan

Figure 7. EASTERN DAN written with full tone marking (1982 orthography)

-Yö -kë yi do ’ka -gbeng waa- ’gbɛn- -wo -kë ”taɔngdëdhɛ ‘gü, ‘wo =niëë wo ‘ko ”piϋ. ‘Yö- -nu -wo -yö -kë do kö -wo ”kpaɔ ‘sü kö -wo ‘dho see” =kwaan-.

Figure 8. EASTERN DAN written with zero tone marking (1982 orthography)

Yö kë yi do ka gbeng waa gbɛn wo kë taɔngdëdhɛ gü, wo niëë wo ko piϋ. Yö nu wo yö kë do kö wo kpaɔ sü kö wo dho see kwaan.

Figure 9. EASTERN DAN written with full tone marking (2019 orthography)

Yɤ̏ kʌ̏ yī dō ká gbɛ̏ŋ wāȁ gbɛ̂n wȍ kʌ̏ tœ̋œŋ̏dʌ̄-dhɛ̏ gɯ́ wó dhìʌʌn wō kó pɪ̋ɤ. Yɤ́’-dhȕn wȍ yɤ̏ kʌ̏ dō kɤ̄ wȍ kpœ̋œ sɯ́ kɤ̄ wȍ dhó sēɛ̋ kwàan.