Koffi, E. (2019). A template model account of lexical stress in Arabic-accented English. In J. Levis, C. Nagle, & E. Todey (Eds.), *Proceedings of the 10th Pronunciation in Second Language Learning and Teaching Conference*, ISSN 2380-9566, Ames, IA, September 2018 (pp. 158-167). Ames, IA: Iowa State University.

PRESENTATION/POSTER

A TEMPLATE MODEL ACCOUNT OF LEXICAL STRESS IN ARABIC-ACCENTED ENGLISH

Ettien Koffi, St. Cloud State University

This study applies Fry's (1958) seminal methodology to investigate how Arabic speakers of English encode and rank F0, intensity, and duration in their pronunciation of disyllabic words. At issue is whether or not Arabic speakers transfer the acoustic correlates of word stress from their L1 into their L2. Al-Ani (1992) found that Arabic speakers encode lexical stress in their L1 by relying overwhelmingly on intensity. Bouchhioua (2008) noted that Tunisian Arabic speakers relied on duration to encode word stress in their L2 English. We explore the issue further by analyzing the pronunciation of 10 Arabic speakers of English who read the Speech Accent Archive text containing seven disyllabic words.

INTRODUCTION

The importance of lexical stress in the intelligibility of L2-accented English is overstated. Confusion persists because the assessment of the role that suprasegmentals play in intelligibility has been largely impressionistic. In this paper, we propose an acoustic phonetic methodology that helps to gauge the role of suprasegmentals accurately. The paper is divided into five main sections. The first provides a quick overview of suprasegmentals in both English and Arabic. The second highlights the main findings on the acoustic correlates of lexical stress. The third gives an overview of the Template Model (TM). The fourth proceeds with the acoustic phonetic measurements of the data. The fifth examines pedagogical implications and applications.

Brief overview of suprasegmentals in English and Arabic

English is classified as a stress-timed language, that is, "some syllables will be longer and some shorter and the intervals between stressed syllables are roughly of equal length" (Fromkin et al. 2017, p. 205). Astruc (2013) and Dehmam and Lobeck (2013) classify Arabic as a stress-timed language. In Arabic and English, syllable-weight determines the placement of lexical stress. Goldsmith (1990) indicates that in Arabic, primary stress falls mostly on super heavy codas, otherwise on penultimate syllables. The same quantity-sensitive stress rule applies to disyllabic words in English. We limit our inquiry to disyllabic words because, according to Lehiste (1970), they are the minimal units where differential stress patterns can be optimally observed. A study of 190,000 English words by Cutler and Carter (1987) reveals that 39% of them are disyllabic. Of these, 90% have primary stress on the penultimate syllable. In other words, disyllabic words overwhelmingly have trochaic feet. Only 10% of English disyllabic words have an iambic foot. For this reason, Chrabaszcz et al. (2014) contend that English speakers have a trochaic bias. Words with trochaic patterns are also commonly found in Arabic (Kenstowicz, 1994). Yet, it remains to be seen whether or not the two languages rely on the same correlate ranking strategy to encode lexical stress.

Ranking of the acoustic correlates of lexical stress in English

The research on the acoustic correlates of lexical stress and their ranking was pioneered by Fry. In three seminal papers, 1955, 1958, and 1965, he found that native speakers of English rely on the following rankings: **Duration > Intensity** (1955), **F0 > Duration > Intensity** (1958), **F0 > Duration > Intensity > F1** (1965). The 1958 ranking is the most widely known and cited. A correlate ranking war of some sort has since ensued. Replication studies have come up with different rankings, including: **Duration > F0 > Intensity**; **Intensity > Duration > F0**; or **F0 > intensity > Duration**, etc. (see Koffi 2018b, pp. 15-16 for an extensive review of ranking and counter-ranking proposals). The ranking of correlates is important because it helps to determine the prosodic strategy that L2 speakers of English of the same L1 background are most likely to rely on in encoding lexical stress. Furthermore, it helps answer the question of whether or not different ranking strategies hinder or facilitate suprasegmental intelligibility.

Correlate ranking in Arabic

Al-Ani (1992), de Jong and Zawaydeh (1999), and Bouchhioua (2008) contain information about the acoustics of lexical stress in Arabic and some ranking of correlates. Al-Ani (1992) found that when speaking in Arabic, Saudi speakers encode lexical stress and rank their correlates as follows: **Intensity > Duration > F0**. de Jong and Zawaydeh (1999) did not rank F0, intensity, and duration but noted quite clearly that duration played an extremely important role in lexical stress in Jordanian Arabic. Bouchhioua (2008) studied Arabic-accented English words produced by Tunisia speakers and found that the participants encoded lexical stress and ranked correlates as **Duration > Intensity > F0**. It is noteworthy that in all these studies, F0 ranks lower than intensity and duration.

Overview of the Template Model

Various models of auditory perception of speech exist. Some are discussed in Massaro and Jesse (2005). The model used in this paper is based on Rabiner's (1999) Template Model (TM) because it makes it possible to assess intelligibility instrumentally instead of doing so impressionistically. An impressionistic assessment of relies on human judges' opinions to determine whether or not a segment or a suprasegment is intelligible. It is by far the most commonly used methodology in pronunciation research, but it is not necessarily the most accurate. The instrumental methodology, on the other hand, gauges intelligibility by measuring the frequency, intensity, and duration imbedded in the speech signals emitted by the talker. Physicist Harvey Fletcher, the inventor of the modern audiogram machine, pioneered this approach (Yost, 2015). In a seminal paper in 1940, he calculated mathematically the frequency responses of speech signals in the basilar membrane. This is now known in acoustic phonetics circle as the Critical Band Theory (CBT). Another physicist, von Bekesy, spent 20 years verifying and confirming clinically that Fletcher's calculations were grounded in physiological reality. For this, Bekesy was awarded the Nobel Prize in Physiology/Medicine in 1961. CBT thresholds have undergone some refinements since then and are now endorsed by the American National Standards Institute (ANSI), the International Electrotechnical Commission (IEC), and other reputable regulatory bodies for the manufacturing of audio products and sound level meters (Pope, 1998). Researchers in a wide variety of fields, audiology, acoustics, automatic speech recognition, speech digitalization, speech synthesis, etc.

rely on CBT thresholds to assess or simulate speech intelligibility. This paper applies relevant CBT-derived thresholds to account for the intelligibility of lexical stress in Arabic-accented English. Proponents of CBT hold that the speech signals emitted by the talkers retain their essential acoustic phonetic properties in the basilar membrane and well into the Central Auditory Nervous System (Yost, 2007, pp. 223-248).

According to TM, for automatic speech recognition by humans or machines, all one needs is a simple algorithm that calculates arithmetic means and standard deviations. A word is automatically recognized if it deviates from the exemplar within acceptable limits of the standard deviation. When TM is applied to the intelligibility of suprasegmentals, we deduce that the closer the acoustic correlates produced by the talker match the exemplar in the mind of the hearer, the more felicitous the recognition. The application of TM calls for knowing the suprasegmental characteristics of lexical exemplars in the hearer's phonological memory. Many linguists, including Fromkin et al. (2017), have given us some clues concerning these suprasegmental characteristics, saying, "In many languages, certain syllables in a word are louder, slightly higher in pitch, and somewhat longer in duration than other syllables in the word. They are stressed syllables" (p. 205).

In order to demonstrate this mathematically, we must first convert impressionistic terms such as "louder," "higher in pitch," and "longer in duration" into measurable and quantifiable correlates. Fortunately, nearly 100 years of psychoacoustic research have made the conversion possible. Important Just Noticeable Thresholds (JNDs) of pitch, duration, and intensity have been discovered which allow us to translate the above-mentioned impressionistic terms into measurable entities. The suprasegmental characteristics of lexical stress can now be restated mathematically as follows:

> A strong/stressed syllable is one whose F0 is ≥1 Hz higher, whose intensity is ≥3 dB louder, or whose duration is ≥10 ms longer than any other syllable(s) within the same word.

The list of authorities who have discussed these JNDs is long and impressive. Suffice it to mention only Lehiste (1970) for the JND in pitch, Moore (2007) for the JND in intensity, and Hirsh (1959) for the JND in duration. These authoritative JNDs are also summarized and discussed in Stevens (2000) and Yost (2007). In the remainder of the paper, we use these JNDs in tandem with TM to account for the intelligibility of lexical stress in Arabic-accented English.

DATA ANALYSIS, PARTICIPANTS, AND ANNOTATION PROCEDURES

The preceding sections have provided the background. Let's now apply these insights to examine how the 10 participants in our study encode lexical stress on disyllabic English words. The corpus comes from George Mason University's Speech Accent Archive (http://accent.gmu.edu/howto.php) and contains relevant sociometric information about the participants. The text contains 69 words, seven of which are disyllabic (10.14%). The disyllabic words and their corresponding IPA transcription are in Table 1. Stressed syllables are highlighted in bold both in spelling and in IPA transcription.

Table 1

IPA transcription of disyllabic words

N0	Word	IPA
1.	St**é**lla	[ˈst**ɛ**lə]
2.	m**á**ybe	[ˈm**e**bi]
3.	br**ó**ther	[ˈbr**ʌ**ðər]
4.	**á**lso	[ˈ**ɔ**:lso]
5.	pl**á**stic	[ˈpl**æ**stɪk]
6.	W**é**dnesday	[ˈw**ɛ̃**nzde]
7.	st**á**tion	[ˈst**e**ʃn̩]

The transcription of lexical stress is based on *Oxford Advanced Learner's Dictionary* (OALD 2000). The nucleus of each syllable is measured according to F0, intensity, and duration, as shown in the annotation in Figure 1 below. The total number of tokens examined in this study is 420 (7 words x 2 syllables x 10 participants).

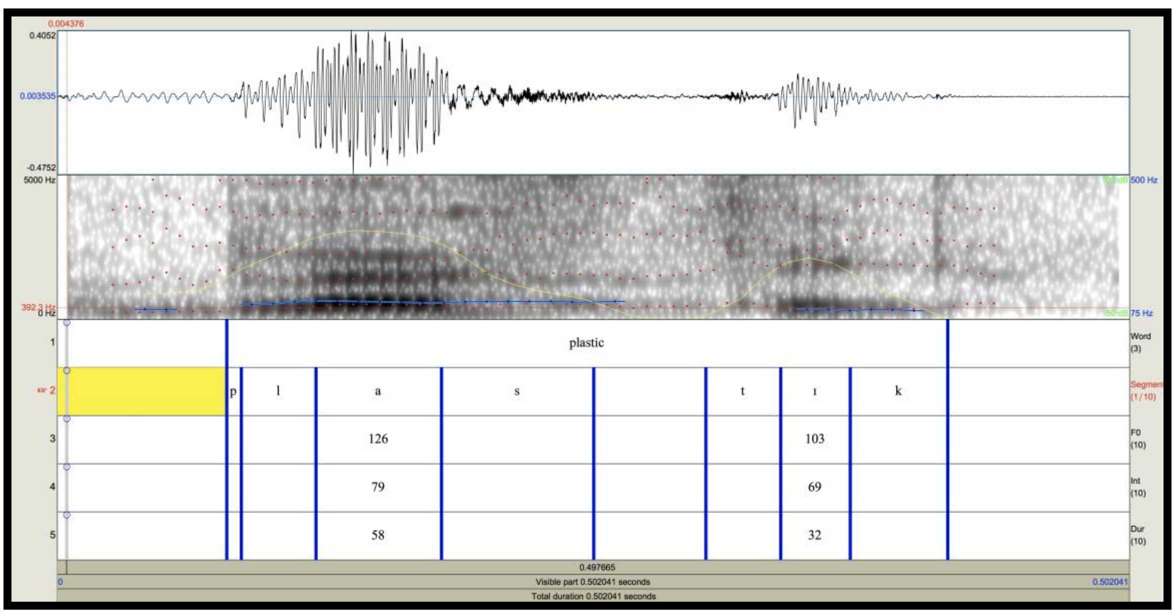

Figure 1. Annotation of "Plastic" by Arabic 36M.

This annotation shows that only the nuclei <a> in <plas> and <i> in <tic> are measured. The same procedure is repeated for all the seven disyllabic words in the data.

Acoustic Measurements of Suprasegments in Arabic-Accented English

The JND thresholds mentioned previously are now applied to account for how the 10 participants encode and rank the acoustic correlates of lexical stress in Arabic-accented English. Tables 2, 3, and 4 display measurements for F0, intensity, and duration. Unless otherwise stated, the analyses focus on the arithmetic means, not on idiosyncratic pronunciations of individual words or participants.

Table 2

F0 measurements

Words	St**é**lla		m**á**ybe		br**ó**ther		**á**lso		pl**á**stic		W**é**dnesday			st**á**tion	
F0	ste	la	may	be	bro	ther	al	so	plas	tic	we	nis	day	sta	tion
Arabic 1F	247	213	254	268	224	256	241	252	229	281	247	257	276	226	208
Arabic 30F	225	204	218	223	218	216	236	286	229	273	220		207	74	275
Arabic 35M	128	145	125	124	114	111	123	114	116	74	108	117	119	84	74
Arabic 36M	128	98	153	98	120	118	142	130	126	103	123		120	105	74
Arabic 40M	116	115	136	120	124	127	154	154	128	112	124		119	101	95
Arabic 44F	187	188	224	248	212	223	222	271	201	156	224		192	149	74
Arabic 46M	103	110	126	136	125	137	128	131	124	141	127	126	127	74	145
Arabic 47M	113	147	117	113	113	94	171	116	113	115	121	128	125	113	92
Arabic 50M	101	108	98	94	84	96	112	111	95	125	102	99	96	88	74
Arabic 51M	119	111	121	122	107	108	129	136	121	116	109		108	75	117
Arabic Mean	**146**	**143**	**157**	**154**	**144**	**148**	**165**	**170**	**148**	**149**	**150**	**145**	**148**	**108**	**122**
St. Dev.	53	43	54	65	52	59	49	70	50	70	56	8	57	47	68

Table 3

Intensity measurements

Words	St**é**lla		m**á**ybe		br**ó**ther		**á**lso		pl**á**stic		W**é**dnesday			st**á**tion	
Intensity	ste	la	may	be	bro	ther	al	so	plas	tic	we	nis	day	sta	tion
Arabic 1F	80	72	81	81	78	77	74	78	79	82	82	80	77	77	72
Arabic 30F	77	74	80	75	82	82	73	78	75	73	78		75	68	64
Arabic 35M	72	76	73	69	76	76	76	72	76	63	74	73	75	66	56
Arabic 36M	76	69	79	69	78	79	83	75	79	69	75		77	71	59
Arabic 40M	75	71	75	76	75	71	80	76	77	72	74		76	69	63
Arabic 44F	75	74	82	72	78	85	79	75	76	73	82		78	76	68
Arabic 46M	73	71	77	75	81	81	83	75	73	73	77	76	76	69	63
Arabic 47M	81	74	81	75	83	77	81	79	80	79	81	81	80	84	70
Arabic 50M	78	80	81	80	78	76	80	75	82	74	81	80	81	71	60
Arabic 51M	74	67	77	76	74	73	79	77	77	71	72		75	66	57
Arabic Mean	**76**	**72**	**78**	**74**	**78**	**77**	**78**	**76**	**77**	**72**	**77**	**78**	**77**	**71**	**63**
St. Dev.	2	3	2	3	2	4	3	2	2	5	3	1	2	5	5

Table 4

Duration measurements

Words	St**é**lla		m**á**ybe		br**ó**ther		**á**lso		pl**á**stic		W**é**dnesday			st**á**tion	
Duration	ste	la	may	be	bro	ther	al	so	plas	tic	we	nis	day	sta	tion
Arabic 1F	85	97	225	99	115	155	234	293	149	127	99	104	241	159	89
Arabic 30F	80	77	97	96	67	33	115	59	81	50	65		74	63	59
Arabic 35M	97	103	146	160	76	60	140	62	91	30	48	60	177	94	39
Arabic 36M	73	40	128	88	110	74	112	55	58	32	88		190	64	70
Arabic 40M	76	89	164	61	72	56	170	84	93	53	59		240	100	41
Arabic 44F	67	72	104	109	55	55	140	39	64	47	112		200	65	52
Arabic 46M	91	78	153	76	50	48	38	79	75	80	77	72	219	102	71
Arabic 47M	159	40	153	125	76	80	140	153	75	157	86	64	278	84	98
Arabic 50M	73	91	84	156	74	61	123	55	51	44	89	93	175	83	57
Arabic 51M	60	95	69	82	55	50	96	75	63	41	75		133	70	88
Arabic Mean	**86**	**78**	**132**	**105**	**75**	**67**	**130**	**95**	**80**	**66**	**79**	**78**	**192**	**88**	**66**
St. Dev.	27	22	46	32	21	33	50	76	27	42	19	16	58	28	20

The JND in F0 shows that in 3 of 7 words (42.85%), the nuclei of the penultimate syllables in <Stella>, <maybe>, and <Wednesday> are at least 1 Hz higher than those of the unstressed syllables. In these cases, the stress pattern conforms to the phonological exemplar in the mental lexicon of native speakers as putatively represented by (OALD, 2000). But such is not the case for <brother>, <also>, <plastic>, and <station>. The JND in intensity indicates that in 4 out of 7 words (57.14%), i.e., <Stella>, <maybe>, <plastic>, and <station>, the nuclei of the penultimate syllables are at least 3 dB louder than the nuclei in the ultima. However, this is not so for <also>, <brother>, and <Wednesday>. The latter is a special case because half of the participants resyllabified it into three syllables. Instead of [ˈwɛ̃nz.de], it turned into [ˈwɛ̃.niz.de]. We see that the nuclei of the penultimate syllables of <maybe>, <also>, <plastic>, and <station> are at least 10ms longer than the unstressed nuclei in <Stella> and <brother>. So, 4 out 7 words (57.14%) conform to the threshold for the JND in duration.

The data in the three tables indicate that lexical stress is produced intelligibly in six words. The only exception has to do with <brother>. According to the exemplar, the F0, intensity, and duration of the vowel [ɑ] in the penultimate syllable should be at least 1 Hz higher, 3 dB louder, and 10 ms longer than the vowel [ə] in the ultima. However, only 4 out 10 participants pronounced <brother> as expected in regard to F0 and intensity. Furthermore, only 2 out 10 produced the duration as expected. Why? It all has to do with the fact that six participants trilled the post-vocalic [r] in the coda of <ther>. Trilling this [r] affects the acoustic correlates of the preceding vowel. Stevens (2000) notes that raising the blade of the tongue to trill [r] increases the F0 of the preceding vowel. In other words, the F0 of [ə] becomes higher than that of [ɑ]. Lehiste (1970) provides an articulatory rationale for why trilling [r] increases the F0 of the preceding vowel, "Now, the muscles constituting the tongue are attached to the superior part of the hyoid bone, and some of the laryngeal muscles are attached to the inferior part. When the tongue is raised, the larynx tends to be pulled upwards and the laryngeal muscles are stretched. This increases the tension of the vocal folds and causes the increase in the vibration rate" (p. 71). Since speakers of many dialects of Arabic trill their [r]s, F0 measurements of the preceding or following vowels may not always conform to the example, as is the case of <brother>.

Correlate ranking

It stems from the measurements and analyses above that the Arabic talkers in this study rely **equally** on intensity and duration to encode lexical stress in English. The ranking of their correlates is as follows: **Intensity (57.14%) = Duration (57.14%) > F0 (42.85%)**. This ranking is consistent with the results in Al-Ani (1992) who found that intensity is the main acoustic correlate of stress in Saudi Arabic and Jong and Zawaydeh (1999) who found that the Jordanian participants in their study relied primarily on duration to encode lexical stress. Our measurements and ranking are in line with both findings in that they show the participants in our study transfer intensity or duration from their L1 to encode lexical stress in their L2 English. There is nothing unusual about this finding because we know from Yost (2007) that "different auditory neurons perceive the different physical components of sounds. Some perceive frequencies, other perceive intensity, while other perceive duration" (p. 223). Since the three acoustic correlates of stress are independent of each other, speakers can use either of them to encode lexical stress. Regardless of the correlates considered, the suprasegmentals in <Stella, maybe, also, plastic, Wednesday, station> are produced and perceived intelligibly. Only the stress pattern of <brother> deviates from the expected trochaic pattern for reasons given in the preceding paragraph.

The intelligibility of suprasegmentals in Arabic-accented English

Yavaş (2011) extrapolates on the basis of syllable weight alone that Arabic speakers of English would misplace the lexical stress on <d**í**fficult>, <**é**xpert>, <n**á**rrowest>, and <**í**nstitute> and mis-stress them as <diffic**ú**lt>, <exp**é**rt>, <narrow**é**st> and <instit**ú**te> because the ultima in all these words are heavy. However, syllable weight is not the only factor nor is it even the determinative factor in assigning lexical stress. The foot structure of the word also plays an important role. De Jong and Zawaydeh (1999) state repeatedly that Arabic and English speakers have similar stress patterns. Consequently, Arabic speakers can bypass syllable weight altogether and adopt a trochaic pronunciation regardless of syllable weight. I have personally interacted with numerous Arabic students, friends, and colleagues, but I have not heard any of them misplace the stress on these words.

Misplaced lexical stress and intelligibility

Yavaş' extrapolation is reminiscent of the type of hyperbolic statements that one encounters frequently in the English L2 pronunciation literature concerning lexical stress. Field (2005) states that "research evidence suggests that suprasegmentals play a more prominent role than segmentals" (p. 402) even though his own paper shows that "incorrect misplacement of lexical stress is, relatively speaking, quite small: affecting only around 8% of content words if every word were misstressed" (p. 417). Claiming that misplacing lexical stress undermines intelligibility betrays a proper of understanding of the auditory and neural processes involved in the perception of suprasegmentals in accent and tone languages (Koffi, 2018a). English is an accent language, not a tone language. Consequently, misplacing lexical stress alone does not and cannot impede intelligibility. Intelligibility is jeopardized only if the words whose stress is mispronounced have lexical competitors, i.e., <p**é**rmit> vs. <perm**í**t>, <**ó**bject> vs. <obj**é**ct>, <c**ó**ntract> vs. <contr**á**ct>, <s**ú**bject> vs. <subj**é**ct>, <r**é**cord> vs. <rec**ó**rd>. However, the total number of such pairs is infinitesimal compared with the tens of thousands of words in English. Even so, misplacing lexical stress on such pairs does not automatically hinder intelligibility because of contextual and syntactic redundancies in spoken utterances. These redundancies allow the hearer to recover the part of speech of words and recognize them accurately. Since English is an accent language, not a tone language, misplacing lexical stress alone cannot and does not interfere with intelligibility. If English were a tonal language, intelligibility would be a different story altogether. In such languages, lexical competitors abound. There may be two, three, four, or even five lexical minimal pairs that are distinguishable from each other by pitch alone. Such is the case of <na> in Thai which has five different meaning depending on pitch fluctuations (Fromkin et al., 2017). The only way that suprasegmentals can play havoc on intelligibility in English is if one or several segments within the same words are **also** severely mispronounced beyond recognition.

PEDAGOGICAL IMPLICATIONS AND APPLICATIONS

Monosyllabic content words that make up 45% of the 190,000 items in Cutler and Carter's (1987) corpus have a predictable stress pattern because they have only strong syllables. The stress pattern of 90% of disyllabic words in their corpus is predictably trochaic because they are of Germanic origin. Arabic speakers would have no problem producing such stress patterns intelligibly. The remaining 10% have an iambic stress pattern. Halle and Chomsky (1999) posit that such words contain the etymological feature [+foreign] in their underlying representation. According to Field (2005), the best way to teach words with non-predictable stress is to draw students' attention to them during vocabulary instruction. Arabic speakers would have no problem producing such words intelligibly if their attention is drawn to their unusual lexical stress pattern.

SUMMARY

The Template Model and the JND thresholds used in this paper allow researchers to gauge the intelligibility of suprasegmentals in L2-English accurately. Since F0, intensity, and duration are three independent and interdependent acoustic correlates, each one by itself or in tandem with others can be used to encode lexical stress. Given that these three acoustic cues are universal and can be combined in various ways to encode lexical stress in English, it is very unlikely that misplacing any one of them can impair intelligibility. This, however, does not mean that lexical stress is not important. It is, but its weight on intelligibility has been exaggerated in complete disregard of the fact that English is an accent language. If it were a tone language like many African languages, Mandarin, or Thai, it would not be an exaggeration to say that misplacing the acoustic correlates of suprasegmentals would lead to frequent communication breakdowns, and/or to occasional embarrassments.

ABOUT THE AUTHOR

Ettien Koffi, Ph.D., is a professor of Linguistics at St. Cloud State University, Minnesota, USA, specializing in acoustic phonetics (Speech Intelligibility). His research interests center around sociophonetic variations in Central Minnesota English, acoustic phonetic accounts of intelligibility in L2 English, and acoustic phonetic and general description of Anyi, a West African Language

spoken in Cote d'Ivoire. He is the author of four books and numerous papers covering topics as varied as syntax, translation, language planning and policy, orthography, and indigenous literacy training manuals. He can be reached at enkoffi@stcloudstate.edu.

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