REANALYZING THE BANDA-LINDA VOWEL SYSTEM

Kenneth S. Olson

SIL International
Ken_Olson@sil.org

ABSTRACT

I reanalyze the Banda-Linda (Ubangian, Central African Republic) vowel system and present a preliminary study of the acoustic properties of the Banda-Linda vowel space. I find that Banda-Linda has nine vowels /i ɨ̞ ɯ̞ u e ə o a ɔ/ instead of the previously reported eight vowels. It includes two high central unrounded vowels /ɨ̞ ɯ̞/ which differ in degree of backness. I do not transcribe /ɨ̞/ as /ɪ/, because there is no significant difference in F1 between /i/ and /ɨ̞/. (A difference in F1 between /i/ and /ɪ/ is typical for ATR or tense/lax contrasts.) There is also no significant difference in F1 between /ɨ̞/ and /ɯ̞/. A system with three vowels differing only in degree of backness calls into question feature models limited to two-way contrasts.

Keywords: acoustic phonetics, vowel space, phonological features, Niger-Congo, Ubangian

1. INTRODUCTION

This paper is a reanalysis of the vowel system of Banda-Linda (ISO 639–3 code = liy), accompanied by a preliminary assessment of the acoustic properties of the vowel space. Banda-Linda is an Ubangian language spoken in eastern Central African Republic by about 183,000 people [21].

Banda-Linda was previously analyzed as having an eight-vowel system /i ɨ u e ə o a ɔ/ [2, 3, 5]. This particular system is rare in the world's languages [12] but common in the Banda subgroup of Ubangian [4, 14, 19]. The system has fewer height distinctions in front vowels than in back vowels, contra a universal put forth by Crothers [6].

In my fieldwork on Banda-Linda, the three language consultants agreed—to my surprise—that Banda-Linda has not one but two high central vowels, /ɨ̞/ and /ɯ̞/. Minimal pairs between /i/, /ɨ̞/, and /ɯ̞/ are given in (1):

(1)	[kə̀lì]	'to be deep'
	[kə̀lɨ̞̀]	'to shave'
	[kə̀lɯ̞̀]	'to be heavy'
	[kə̀tì]	'to look, watch'
	[kə̀tɨ̞̀]	'to peel'
	[kə̀tɯ̞̀]	'to support'

This results in the system shown in Table 1:

Table 1: The Banda-Linda vowel system

	front	central	back
high	i	ɨ̞ ɯ̞	u
mid	e	ə	o
low		a	ɔ

This system exhibits the rarity of three high unrounded vowels that differ in backness [10, 15]. Because of the rarity of this system, I conducted an acoustic study to examine more closely the characteristics of the three vowels /i ɨ̞ ɯ̞/. I also collected video footage to confirm that the three sounds are unrounded.

2. GENERAL PROCEDURES

2.1. Subject

A 43-year-old male native speaker of Banda-Linda participated in this experiment. The subject grew up in Bambari and moved to Bangui permanently at the age of 39. He has completed a university degree (*licence*). Besides Banda-Linda, he also speaks Sango, French, and Nzakara.

2.2. Procedures

The recording took place at the ACATBA Center (Association Centrafricaine pour la Traduction de la Bible et l'Alphabétisation) in Bangui, Central African Republic. The data were collected in an office familiar to the subject. The subject was seated and read prompts on sheets of paper in a transcription familiar to him.

During the recording session, the author produced the gloss for each word in French, and then the subject produced the corresponding word in Banda-Linda twice.

The audio data were recorded at 48k, 24-bit using a Zoom H2 recorder, and saved as WAV files. A video was made of words spoken in isolation that include the high vowels, using a Samsung Galaxy J3 Pro smart phone.

Other stimuli were interspersed with these to address a variety of questions, and these sets served as distractors from each other.

2.3. Analysis

Measurements were made of the first three formants for each vowel. Formant frequencies were measured using the following criteria. First, a wide-band spectrogram of each token was visually inspected to verify that there was a steady state period of the vowel. Then the midpoint of the steady state was visually identified. The window of analysis was centered on this midpoint.

Formant measurements were made using the LPC analysis feature in Praat (version 6.0.37) employing its default parameters, with the exception that “Maximum formant (Hz)” was set to 5,000 Hz and “Number of formants” was set to 6.0. The formant measurements were verified by visual inspection of a wide-band spectrogram.

3. VOWEL SPACE

I first examined the Banda-Linda vowel space. Twelve tokens of each vowel were analyzed, most in an open syllable following an alveolar consonant. Two tokens of each vowel consisted of the vowel spoken in isolation. I avoided adjacent nasal consonants in order to minimize the influence of nasalization [9]. The mean values of F1, F2, and F3 are shown in Table 2.

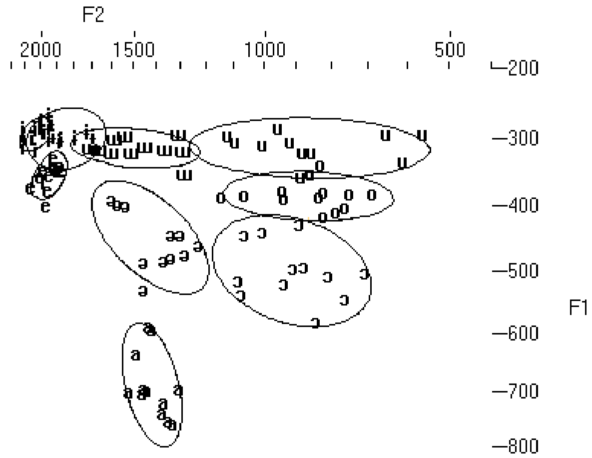
Table 2: Mean values of F1, F2, and F3 for each vowel. Units are Hertz.

vowel	F1	F2	F3
i	277	2,061	2,660
ɨ̞	283	1,873	2,427
ɯ̞	296	1,535	2,287
u	297	886	2,234
e	337	1,976	2,504
ə	430	1,449	2,414
o	368	884	2,373
a	668	1,439	2,392
ɔ	481	933	2,429

Figure 1 shows a plot of F1 vs. F2 [18] created using the Windows version of the UCLA PlotFormants program (version 4.0). A vowel symbol is given for each individual token. The axes are marked in Hertz, but scaled on the Bark scale, which reflects the ear’s sensitivity to differences in pitch [23]. The ellipses are centered on the mean for each vowel and have radii of two standard deviations [13]. There is reasonable separation between most of the vowels, indicating that the values of F1 and F2 are sufficient acoustic properties for distinguishing the vowels.

The vowel /i/ has a slightly lower F1 value than /u/, which is a crosslinguistic tendency [7], and the mean values of F1 for /ɨ̞/ and /ɯ̞/ are between those of /i/ and /u/. The mean values of F1 for the four high vowels are within a 20 Hz range, which suggests that their categorization as high vowels is warranted.

Figure 1: F1 vs. F2 plot of the vowels in Banda-Linda. Units are Hertz.



A comparison of F1 means for the high vowels /i ɨ̞ ɯ̞ u/ using a single factor ANOVA was significant [F(3,44)=3.324; p<0.05]. Post hoc comparisons showed significance for two comparisons: /i/ vs. /ɯ̞/ [t(22)=3.46, p<0.01 (one-tailed)], and /i/ vs. /u/ [t(17)=2.69, p<0.01 (one-tailed)]. Other comparisons between high vowels were not significant, including the adjacent ones [/i/ vs. /ɨ̞/: t(17)=0.82, p=0.212 (one-tailed); /ɨ̞/ vs. /ɯ̞/: t(22)= –1.65, p=0.057 (one-tailed); /ɯ̞/ vs. /u/: t(19)=0.13, p=0.45 (one-tailed)].

F1 is the primary acoustic property distinguishing /i/ from /ɪ/ in ATR and tense/lax languages that contrast the two sounds, often differing by more than 100 Hz [22, 18, 11]. Since the difference between the F1 values of /i/ and /ɨ̞/ is small, to the point of not differing significantly in my analysis, I do not transcribe /ɨ̞/ as /ɪ/.

Analyzing a larger number of tokens for each vowel would likely lead to more post hoc comparisons showing significance. Regardless, the small difference in F1 between /i/ and /ɨ̞/ would not warrant a reanalysis in terms of ATR or tenseness.

Despite the ellipse overlap, a comparison of the F2 means for the vowels /i ɨ̞ ɯ̞/ using a single factor ANOVA was very highly significant [F(2,33)= 60.85; p<0.001], as were post hoc comparisons [/i/ vs. /ɨ̞/: t(16)= –5.01, p<0.001 (one-tailed), /ɨ̞/ vs. /ɯ̞/: t(22)= –5.93, p<0.001 (one tailed)].

Also, a comparison of the F3 means for the vowels /i ɨ̞ ɯ̞/ using a single factor ANOVA was very highly significant [F(2,33)=46.45, p<0.001], and post hoc comparisons were significant as well

[/i/ vs. /ɨ̟/: t(22)= –6.34, p<0.001 (one-tailed); /ɨ̟/ vs. /ɯ̟/: t(22)= –3.46, p<0.01 (one-tailed)].

The mean values of F2 for /ɨ̟ ɯ̟/ in Banda-Linda are much greater than the typical values of F2 for the vowels /ɨ ɯ/ in general [20]. This is why I transcribe these two sounds using the advanced diacritic [̟] and consider /ɯ̟/ to be central rather than back. That being said, the vowel system would still have three high unrounded vowels if /ɯ̟/ were construed as being back rather than central.

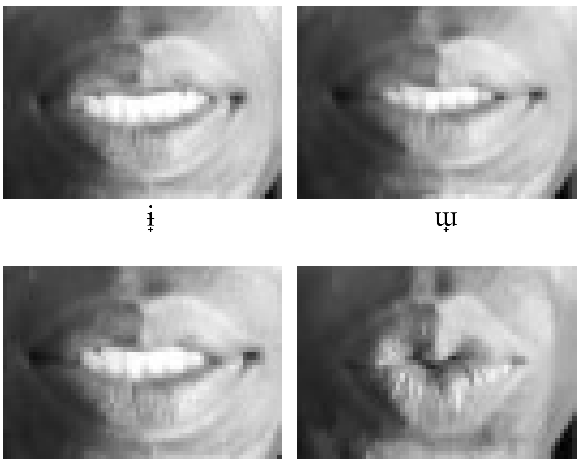
In summary, the values of F2 and F3 serve to distinguish the vowels /i ɨ̟ ɯ̟/, mostly at the level of very high significance. The F1 values of /ɨ̟ ɯ̟/ vis-à-vis /i u/ provide support for their categorization as high vowels.

4. LIP POSITION

Another parameter that can distinguish vowels is lip rounding. Videos were made of lip configurations of the high vowels in order to determine if rounding or degree of aperture contributed to the acoustic qualities of the vowels. The subject produced a series of verbs containing each high vowel with a preceding alveolar plosive. The verbs were produced in isolation.

Video frames showing the production of each high vowel are given in Figure 2. The front vowel /i/ and the central vowels /ɨ̟ ɯ̟/ all have nearly the same lip configuration. In the horizontal dimension, the mouth corners appear to be the same distance apart for /i/, /ɨ̟/, and /ɯ̟/. In contrast, /u/ is clearly rounded, with the mouth corners brought closer together in the horizontal dimension. In the vertical dimension, the aperture for /ɯ̟/ appears to be slightly narrower than for /i/ and /ɨ̟/. A more detailed study would be necessary to determine if this difference is significant.

Figure 2: Representative images of lip position for the vowels /i ɨ̟ ɯ̟ u/.



5. DISCUSSION

To recap, the vowels /i ɨ̟ ɯ̟/ all have very similar F1 values, and their values of F2 and F3 decrease as one moves from left to right on the vowel chart. In addition, their lip configurations are nearly identical, showing no signs of rounding. This all supports the view that the three vowels should be classified as high and unrounded, and that they exhibit a three-way contrast in degree of backness.

Duanmu [8] proposes a phonological feature theory in which he claims a two-way contrast for each feature is sufficient for distinguishing all known phonemic contrasts. As an example, he discusses the case of Nimboran (ISO = nir), which has a putative three-way contrast between /i/, /ɨ/, and /ɯ/ [1, 10, 11]. He dismisses this particular case because of the possibility that /ɨ/ and /ɯ/ may differ in tenseness. For Banda-Linda, the small difference in the mean values of F1 between the phonemes /ɨ̟/ and /ɯ̟/ (13 Hz) suggests that the distinction between the two vowels should not be attributed to tenseness.

Bora (ISO = boa) is another case that calls into question Duanmu’s claim [15, 16, 17]. Bora has three high unrounded vowels transcribed as /i ɨ ɯ/, but no high rounded vowel /u/. Acoustically, /ɨ/ and /ɯ/ are clearly high vowels, and the values of F2 and F3 decrease for the high vowels as one moves from left to right on the vowel chart. One acoustic difference is that the formant peaks for /ɯ/ are less prominent than those for /i/ and /ɨ/. Articulatorily, /ɨ/ exhibits lingual-dental contact.

The evidence from Banda-Linda thus adds to the growing body of literature that shows that three-way distinctions in certain features may be necessary to model phonological systems accurately.

This study is preliminary. First, I have provided data from only one subject. A larger number of subjects would likely more accurately reflect the speech community at large. Ladefoged [9] suggests testing a half-dozen speakers of each sex.

Second, other parameters could be examined. While my acoustic study provides support for the absence of tenseness or tongue root movement as features in Banda-Linda, this could be bolstered by an imaging study (e.g. ultrasound) to add further verification. While length is not contrastive in Banda-Linda, an examination of that parameter could rule it out as a factor. A more rigorous study of lip position could be informative. Finally, other acoustic factors could be examined, including formant prominence and bandwidth.

6. ACKNOWLEDGMENTS

I wish to thank Clarence Mbakossi-Nede, Pascal-Isidore Dakpa, and Alfred Siango for their collaboration and friendship, ACATBA for meeting and recording space, Brad Festen, Jeff Mielke, Paul Murrell, Steve Parker, and three anonymous reviewers for helpful comments, and the SIL Central African Republic Service Group for funding.

7. REFERENCES

[1] Anceaux, J. C. 1965. *The Nimboran Language: Phonology and Morphology*. The Hague: Nijhoff.

[2] Cloarec-Heiss, F. 1967. *Essai de phonologie du parler banda-linda de Ippy*. Paris: SELAF.

[3] Cloarec-Heiss, F. 1969. *Banda-Linda de Ippy: phonologie - dérivation et composition*. Paris: SELAF.

[4] Cloarec-Heiss, F. 1978. Étude préliminaire à une dialectologie banda. In: Boyd, R., Cloarec-Heiss, F. (eds), *Études comparatives*. Paris: SELAF, 11–42.

[5] Cloarec-Heiss, F. 1986. *Dynamique et équilibre d'une syntaxe: Le banda-linda de Centrafrique*. Paris: SELAF.

[6] Crothers, J. 1978. Typology and universals of vowel systems. In: Greenberg, J. H. (ed), *Universals of Human Language 2: Phonology*. Stanford: Stanford University Press, 93–152.

[7] de Boer, B. 2011. First formant difference for /i/ and /u/: A cross-linguistic study and an explanation. *J. Phonetics* 39, 110–114.

[8] Duanmu, S. 2016. *A Theory of Phonological Features*. Oxford: Oxford University Press.

[9] Ladefoged, P. 2003. *Phonetic Data Analysis*. Oxford: Blackwell.

[10] Ladefoged, P., Maddieson, I. 1990. Vowels of the world's languages. *J. Phonetics* 18, 93–122.

[11] Ladefoged, P., Maddieson, I. 1996. *Sounds of the World's Languages*. Oxford: Blackwell.

[12] Maddieson, I. 1984. *Patterns of Sounds.* Cambridge: Cambridge University Press.

[13] Maddieson, I., Anderson, V. 1994. Phonetic structures of Iaai. *UCLA Working Papers in Phonetics* 87, 163–182.

[14] Olson, K. S. 2005. *The Phonology of Mono*. Dallas: SIL and University of Texas at Arlington.

[15] Parker, S. 2001. The acoustic qualities of Bora vowels. *Phonetica* 58, 179–195.

[16] Parker, S., Mielke, J., Pennington, F. 2017. A comparison of lip positions for /ɨ/ and /ɯ/ in Bora. *J. Acoust. Soc. Am*. 141, 3579.

[17] Parker, S., Mielke, J., Pennington, F. 2018. Phonetic study of /ɨ/ and /ɯ/ in Bora. Poster presented at the LSA meeting, Salt Lake City, January 4, 2018.

[18] Peterson, G. E., Barney, H. L. 1952. Control methods used in a study of the vowels. *J. Acoust. Soc. Am.* 24, 175–184.

[19] Sampson, D. 1985. The phonology of Banda-Tangbago. *Studies in African Linguistics*, Supplement 9, 269–274.

[20] Schwartz, J.-L., Boë, L.-J., Vallee, N., Abry, C. 1997. The Dispersion-Focalization Theory of vowel systems. *J. Phonetics* 25, 255–286.

[21] Simons, G. F., Fennig, C. D. (eds). 2018. *Ethnologue: Languages of the World*, 21st edition. Dallas: SIL International.

[22] Starwalt, C. G. A. 2008. The acoustic correlates of ATR harmony in seven- and nine-vowel African languages: A phonetic inquiry into phonological structure. University of Texas at Arlington dissertation.

[23] Zwicker, E., Terhardt, E. 1980. Analytical expressions for critical-band rate and critical bandwidth as a function of frequency. *J. Acoust. Soc. Am.* 68, 1523–1525.