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The non-lax question prosody of Akan

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Abstract

The paper investigates the acoustics of the final vowel in string-identical Yes-No questions and statements in Akan, a Kwa languages classified as belonging to the group of lax prosody languages. Several spectral measures and measure of periodicity are presented. Results show that the final vowels of Yes-No questions are not characterized by lax laryngeal settings. The final vowel of Yes-No questions is produced with more speech effort due to an additional tonal target at the right edge of the question (L%). The question prosody of Akan thus exhibits non-lax characteristics.

Index Terms: African tone language, Yes-No question, prosody, vowel quality

1. Introduction

1.1. African question prosody

[1] and [2] classify the intonation of Yes-No questions (YNQ) in African languages into two main categories: H(igh)-pitched and non-H-pitched question intonation. H-pitched question markers include solely f0 related parameters such as pitch-register expansion, addition of a final H boundary tone(H%)/rising intonation or cancellation/reduction of final lowering amongst others whereas non-H-pitched markers constitute f0 related parameters such as L(ow)%/falling intonation, duration related parameters such as (final) lengthening or addition of an open vowel and vowel quality parameters such as breathy termination amongst others [1:37-38]. In [1] and [2], Akan is classified as member of the non-H-pitched question intonation camp, but see 1.3.

[1:46-51] observes a frequent co-occurrence of final falling intonation and final lengthening which may be accompanied by breathy termination and a steady intensity decrease in nearly all the languages of the Niger-Congo phylum, in several languages of the Nilo-Saharan and in the Chadic family of the Afro-Asiatic phylum; see also [3] for an overview on the clustering of breathy phonation and lowered tone. As a result, [1] suggests the cover term lax prosody to capture the characteristics of the laryngeal settings evoking the articulation of non-H-pitched YNQs. According to [2:929)], lax prosody is synonymously with lax voice. [4:451] suggest the phonation of lax voice may be similar to breathy voice (softer sound and lower pitch than modal voice), which involves minimal laryngeal tension. However, the tension parameters of the entire vocal tract and the larynx may be at an intermediate level between modal and breathy, see section 1.4 for further details on breathy phonation. In the current study the label breathy voice will be used as cover term for any voice quality that is produced with a lower degree of laryngeal effort than the reference category, which is the final vowel of statements. According to [1], lax prosody is the opposite of tense prosody which characterizes the laryngeal settings accompanying the H-pitched question markers.

[2] identifies a few languages that combine H-pitched (tense) and non-H-pitched (lax) question parameters in the Kordofanian languages, in the Nilo-Saharan languages and also in the Niger-Congo languages, see section 1.2 for further details

1.2. Question prosody in other Niger-Congo languages

[2] reports that nearly all languages of the Gur, Kwa, Mande, Ijoid and Kru families and several non-Bantu languages of the Benue-Congo family exhibit some form of lax prosody, whereas nearly all languages of the Atlantic family and the Bantu languages do not show lax prosody. [1] and [2] describes a few languages as hybrid question prosody languages, in particular Baule, Bambara and the Kolukuma dialect of Izon. Baule is a Kwa language spoken in the Ivory Coast. It combines L% with pitch-register expansion. Bambara is a Mande language spoken in Mali. It uses a final /-a/ or /-wa/ with rising intonation. Izon is an Ijoid language spoken in Nigeria. It combines L% with high tone raising. A growing body of experimental research, building on work by [1] and [2], suggests that hybrid question prosodies are quite common.

[5] investigates the question prosody in the Gur languages Buli, Deg, Safaliba and Kɔnni, and the Kwa languages Adele, Chumburung spoken in Ghana. He shows that all of the selected languages exhibit show some kind final F0 fall and final lengthening in combination with pitch-register raising. All selected languages except Chumburung exhibit an expanded pitch-register. Out of the 6 languages of [5]'s sample only Chumburung and Deg can be described as terminating breathy.

[6] shows for Ikaan, a West African Benue-Congo language of the Niger-Congo phylum spoken in Nigeria, that it uses final lengthening, breathy phonation plus voicelessness, a larger final F0 fall in combination with pitch-register raising. She further observes that intensity is overall higher in questions and mentions that intensity is not easy to integrate into the lax/tense distinction since it is not modulated by laryngeal settings.

1.3. Akan language background

Akan (ca. 8.3 million speakers) is a Kwa language of the larger Niger-Congo phylum spoken in Ghana. It is a cover-term for several dialects [7]. The data in this paper stem from one of the major dialects: Asante Twi. For ease of exposition, I will use the name Akan throughout the paper. The basic word order is SVO. Akan contrasts L, which will be marked with a grave accent, and H tone, which will be marked with an acute accent, in its grammar. It is level-tone languages and exhibits downdrift: the stepwise lowering of H tones in a sequence of alternating L and H tones [7]. Akan does not have lexical stress.

The prosody of Akan is experimentally relatively well studied, see e.g. [8], [9] and [10] amongst others for recent works, [10] for a summary on tonal processes and [11] for information on vowel harmony and prosodic phrasing. Recently, [12], building on works by [7] and [8] amongst others, show experimentally that YNQs are realized in a raised pitch-register without pitch-register expansion, that the

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sentence-final element is longer, that it has a higher intensity and a larger F0 fall compared to string-identical statements. [12] thus propose that Akan is a hybrid question prosody type, in the sense of [2], since it combines H-pitched and non-H-pitched question parameters. Final lengthening and final falling F0 are classic lax prosody markers [2]. However, [8], investigating the presence and length of the breathy termination, shows that it optionally occurred in both statements and YNQs. Furthermore, the final vowel of YNQs is not characterized by an intensity decrease, which would be expected for lax voice but by an intensity increase [8], [12]. Based on their empirical findings [8] and [12] broach the issue of the adequacy of the categories lax and tense in [1] and [2]'s classification; see also [6].

[8] and [12] propose that final lengthening and the final fall in YNQs are not caused by lax voice but rather induced by tonal crowding due to an additional tonal target (L%) at the right edge of the utterance. They describe that the final vowel of YNQs does not sound soft/breathy but rather tense and powerful, i.e. the final vowel of YNQs is articulated with an increased speech effort relative to the final vowel of statements. The aim of the current paper is to substantiate this claim by using vowel quality measures.

1.4. Acoustic measures of breathiness

Relative to modal phonation, the vocal chords during breathy phonation are fairly adducted and exhibit little longitudinal tension, e.g. [4]. The airflow is more and continuous due to a less constricted glottis, i.e. a larger open quotient [13]. The glottal closure is less abrupt. The increased, uninterrupted airflow results in the generation of aperiodic aspiration noise. The vibrating vocal folds generate periodic voicing with more rounded glottal pulses. The source spectrum thus contains both harmonics and random noise [14]. [15] further observe that breathy phonation is characterized by lower acoustic intensity, lower F0 and weaker higher frequencies in relation to modal phonation in many languages, see also section 1.1. Spectral characteristics can be measured as spectral balance or spectral tilt. The periodicity of the signal can be measured using cepstral peak prominence, harmonics-to-noise ratio or the center of gravity.

Spectral balance captures the difference between the amplitude of the first harmonic (H1) and the second harmonic (H2). Due to the increased airflow, the amplitude of H1 is greater in relation to H2. Thus, H1-H2 values are expected to be higher for breathy vowels than for modal vowels, see e.g. [13] for four minority languages of China, [16] for Jalapa Mazatec, [17] for Chanthaburi Khmer and [18] for Gujarati. Spectral tilt is measured as the difference between the amplitude of the first harmonic (H1) and the harmonics at the first, second and third formant (A1, A2, A3). H1-A1 is used as an indirect measure of F1 bandwidth, following e.g. [17]. Bandwidth is related to the rate of energy loss in the vocal tract [19]. F1 bandwidth is expected to be greater for breathy vowels than for modal vowels since the posterior glottal opening widens the bandwidth. H1-A1 values have been found to be higher for breathy vowels than for modal vowels in e.g. [18] for Gujarati, [17] for Chanthaburi Khmer. The less abrupt glottal closure weakens the higher harmonics, which results in a higher spectral tilt, i.e. H1-A2/A3 values are expected to be higher for breathy vowels than for modal vowels, see e.g. [16] for Jalapa Mazatec (H1-A2), [17] for Chanthaburi Khmer (H1-A3) and [20] for Takhian Thong Chong (H1-A2/A3).

The similarity of the waveform shape in adjacent cycles can be measured by the harmonics-to-noise ratio (HNR), as established by [21]. Breathy vowels exhibit lower HNR values since they have more aperiodic noise than modal vowels, see e.g. [22] and [17] for Javanese, and [18] for Gujarati.

To measure the frequencies in a spectrum, the spectral center of gravity (CoG) can be used. CoG values are lower for breathy vowels, see e.g. [23] for English. For Dutch and English, a higher CoG correlates with perceived sentence accent (more speech effort), whereas de-accentuation results in vowel reduction and exhibits a lower CoG (less speech effort) [24] and [25]. Further, the steepness of the spectral slope is determined by the steepness of the glottal pulse which is a measure of speech effort [25].

Another measure is the cepstral peak prominence (CPP), as defined by [26]. It measures the relative amplitude of the cepstral peak prominence and relates it to the expected amplitude (predicted by linear regression). CPP is lower in breathy than in modal phonation due to the added noise, i.e. less regularity and lower periodicity, see e.g. [18] for Gujarati and [20] for Takhian Thong Chong.

It should be noted that the articulatory configurations involved in the generation of breathy phonation and hence the acoustic characteristics may vary within and across languages [27]. The measures presented are used to test whether the YNQs of Akan terminate breathy.

2. Production experiment

2.1. Materials

To investigate the vowel quality of YNQs of Akan, I re-used data of string-identical YNQs and statements published in [8], [12]. Out of this data pool, a particular subset was created. The final vowel was chosen as measuring zone since [2] identifies it as domain of breathy termination. The criterions for selection were vowel quality and tone. The vowel should be maximally unmarked; hence final /a/'s were selected. Since L toned vowels are on average 80-100 ms shorter than H toned vowels [28] and a certain length is desirable to obtain reliable voice quality measures, only H toned vowels were selected. The material consists of 4 YNQ/statement pairs with alternating tones and final H tone and 2 YNQ/statement pairs with H tones only. An example is given in (1).

Ánàné bɪ̀sá
proper name ask.HAB
'Anane asks./Anane asks?' (1)

2.2. Procedure and participants

All participants were recorded at a sampling frequency of 44.1 kHz and 32 bit resolution, directly on a laptop (Levono R61) with a headset (Logitech Internet Chat Headset). The experiments were carried out in a quiet room. The material was presented in a pseudo-randomized order with the use of presentation software. Each sentence was presented on a separate slide. Items from other unrelated experiments were interspersed as fillers. The target-to-filler ratio was 1:2.5 on average. All test sentences were prepared in Akan orthography with English translation below the target sentence. Sentence mode was signaled visually by either question mark (?) or period (.). The participants got the instruction to read the sentence on the slide silently and consult the English translation in case of tonal ambiguities. After this step, they were asked to produce the sentence aloud. The presentation flow was self-paced.

23 native speakers of Akan (8 female, 15 male) participated in the experiments. All subjects declared English as their second language. All of them were students and their

average age was 26.5. Each speaker was paid a small fee for participation.

In total 212 sentences are analyzed in the current study (4 items with alternating tones x 3 repetitions x 6 speakers (1 female, 5 male) x 2 conditions = 144 sentences plus 2 items with H tone only x 17 speakers (7 female, 10 male) x 2 conditions = 68 sentences).

2.3. Acoustic and statistical analysis

The data was pre-processed as follows: the final vowel was labelled in Praat [29] according to principles stated in [16:173]. Following that, the labeled final vowel was divided into four equally spaced intervals with the use of a Praat-script, which I refer to position 1-4 henceforth.

I measured H1-H2, H1-A1, H1-A2 and H1-A3 in dB at the temporal mid of each interval using a Praat script. In cases in which the Harmonics were not tracked properly, the obtained values were manually corrected. Furthermore, CPP in dB, CoG in Hz and mean HNR in dB were measured in Praat [29] for each interval, see [30] for details.

There have been several data losses. In 10 cases the vowel was articulated very weak, hence it was not possible to obtain any meaningful values. Out of these 10 cases was one YNQ. Furthermore, four YNQs of a male speaker had to be discarded from the analysis since he produced a /ə/ in the final position. 28 HNR values could not be tracked. Out of this 28 HNR values were 14 YNQs. In particular, six HNR values at the first position, six HNR values at the second position, 12 HNR values at the third position and 19 HNR values at the fourth position were discarded.

The results of the phonetic analysis are evaluated against the fixed factors SENTENCE MODE with the two levels and POSITION with four levels (with interaction term) in R [31] using linear mixed models from the 'lme4' package [32]. The reference level for SENTENCE MODE is statement (S) and the final interval (4) POSITION. Random intercepts for speaker and item and by-speaker and by-item random slopes [33] for sentence mode and position are integrated into the models. A t>1.96 is taken to indicate significance.

For all measures except CoG, I expect no main effect of SENTENCE MODE since according to [8] and [12] the final vowel of YNQs is articulated with more speech effort than the final vowel of the statements and breathy termination appears for both sentence modi (optionally). Whereas a main effect of POSITION is expected because final syllables generally tend to terminate breathy, see [14:821] for American English]. No interaction between the fixed factors is expected. I only report detailed figures on the significant results.

3. Results

3.1. Spectral measures

The results of the statistical analysis for the spectral measures are listed in table 1. A significant main effect appears for POSITION 4 vs. POSITION 2 for all variables and additionally for POSITION 4 vs. POSITION 1 for H1-H2. H1-A1/A2/A3, but not H1-H2, show a significant main effect for SENTENCE MODE. None of the other comparisons or the interaction yield significant results.

Table 1: *Results of the statistical analysis of the spectral measures*

Variable		Estimate	SE	t
H1-H2	Intercept (S,4)	-1.482	0.586	2.531
in dB	Position 1	-1.021	0.245	4.172
	Position 2	-0.683	0.201	3.403
H1-A1	Intercept (S,4)	-9.322	1.683	5.538
in dB	YNQ	0.903	0.309	2.924
	Position 2	1.298	0.342	3.802
H1-A2	Intercept (S,4)	-3.51	1.375	2.552
in dB	YNQ	1.507	0.458	3.294
	Position 2	-1.307	0.359	3.639
H1-A3	Intercept (S,4)	7.226	1.675	4.315
in dB	YNQ	1.187	0.311	3.823
	Position 2	-0.99	0.408	2.429

The mean values, averaged over speakers, items and repetitions, of the spectral measures plus standard errors at the four positions are displayed in figure 1.

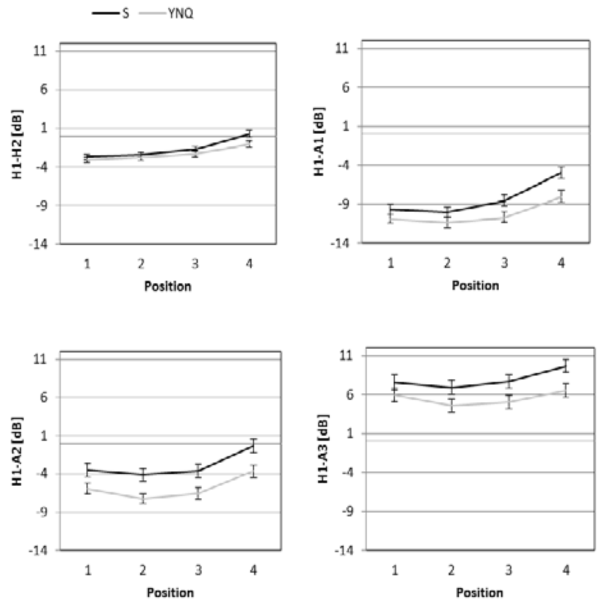

Figure 1: *Mean values, averaged over speakers, items and repetitions, and standard error of the spectral measures in dB split by sentence mode and position.*

3.2. Measures of periodicity

The significant results of the statistical analysis for the measures of periodicity (CoG) are listed in table 2. A significant main effect appears for POSITION 4 vs. POSITION 1 and POSITION 3 for the CoG. CoG also shows a significant main effect for SENTENCE MODE. None of the other comparisons or the interaction yield significant results.

Table 2: *Results of the statistical analysis of the CoG*

Variable		Estimate	SE	t
CoG	Intercept (S,4)	845.991	34.949	24.213
in Hz	YNQ	-29.976	13.351	2.245
	Position 1	-57.98	14.934	3.882
	Position 3	29.756	10.558	2.818

The mean values, averaged over speakers, items and repetitions, of the CoG plus standard errors at the four positions are displayed in figure 2.

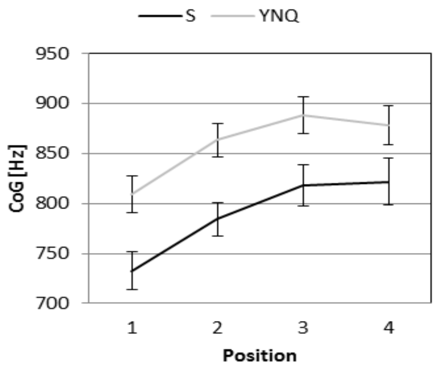

Figure 2: *Mean values, averaged over speakers, items and repetitions and standard error of the CoG in Hz split by sentence mode and position.*

4. Discussion

As expected, the values for the spectral balance H1-H2 of the final vowels do not differ systematically between the conditions. The final vowels of YNQs and statements exhibit a higher H1-H2 at the final position than at the earlier positions which was expected from observations made by [14]. However, the H1-H2 values at the earlier positions (1-3) are negative, which means that the amplitude of H2 is greater than the amplitude of H1. According to [4], a relatively strong H2 indicates tense or creaky voice. Negative values in particular for male speakers have been found in Chanthaburi Khmer [17]. The present data may be interpreted in the same vain, namely that the final vowel of both statements and YNQs is rather tense at positions 1-3 and rather lax at position 4. H1-H2 values of truly breathy vowels, i.e. vowels that terminate breathy, are expected to be positive.

Contrary to the expectation, H1-A1 values are consistently higher for the statements than for the YNQs indicating that the final vowels of statements are “breathier” than the final vowels of YNQs, i.e. the former have a narrower F1 bandwidth [34]. Again, values are overall negative which means that the amplitude of A1 is greater than the amplitude of H1. For the final vowels of both sentence modi, the F1 bandwidth decreases toward the end of the vowel which is reflected in the consistently higher values at position 4 in relation to position 2.

H1-A2 values are also consistently higher for the statements than for the YNQs indicating that the final vowels of statements are “breathier” than the final vowels of YNQs, contrary to the expectation. Again, values are overall negative which means that the amplitude of A2 is greater than the amplitude of H1. Negative values have been reported by [35] for laryngealized vowels in Jalapa Mazatec. [14:821] report on two implementation strategies for the starting of arytenoid cartilages departure in preparation for breathing; the “relaxed” mode and the “laryngealized” mode. The latter is rather associated with male speakers, which constitute the predominant sex in the current study. The “laryngealized” mode is associated with a rotational motion. The values of H1-A2 are higher for the final vowels of both sentence modi at the final position 4 than at the earlier position 2. The amplitude of A2 is decreasing towards the end of the utterance.

The H1-A3 values are also consistently higher for the statements than for the YNQs indicating that the final vowels of statements are “breathier” than the final vowels of YNQs, contrary to the expectation. However, values are overall positive which means that the amplitude of H1 is greater than the amplitude of A3. Positive values have been suggested to reflect glottal rounding, see [17] and references therein. As for all other spectral measures, the values of H1-A3 are higher at the final position 4 than at the earlier position 2 for both sentence modi. The amplitude of A3 is also decreasing towards the end of the utterance.

As expected, the HNR measures are not lower for the final vowels of YNQs than for the final vowels of statements. Unexpectedly, there was also no effect of position. [17] report for Chanthaburi Khmer that HNR did not differentiate clear from breathy vowels. Either the final vowels of Akan are not terminating breathy or HNR does not correlate with breathiness in Akan.

Also the CPP does not show a lower value for the final vowels of YNQs, which is in line with the expectation. Contrary to the expectations, there was also no effect of position. [20] suggests that the behavior of the CPP values may help to clarify H1-H2 results. [36] report that the aperiodicity associated with creaky phonation may lower both H1-H2 and CPP. Since CPP is not lowered, it is likely that final vowels of Akan, especially in YNQs, are rather tense than creaky.

Finally, the CoG values are, as expected, higher for the final vowels of YNQs than for the final vowels of the statements which are taken as indication that the final vowel of YNQs is produced with more speech effort [24, 25] rather than reflecting a more front place of articulation of the vowels of YNQs [37]. [8] observes no change in the formant structure as a function of sentence mode. The finding thus complements the observation that the final vowels of YNQs are produced with a higher intensity than the final vowels of statements [8], [12]. The unexpected effect that the CoG is lower at position 1 than at position 4 may be due to the transition from the preceding consonant. Fricatives, as in (1), tend to make the beginning of the vowel breathy [38]. As expected, CoG is lower at position 4 than at position 3.

The findings suggest that the variation amongst the lax prosody languages is more divers and goes beyond the expected non-H-pitched markers assumed by [1] and [2]. The results show that the final vowels of statements exhibit rather lax laryngeal tension settings and the final vowels of YNQs rather tense laryngeal tension settings. The opposition modal/breathy seems not to be appropriate. It remains to be shown whether the tense/lax opposition plays a further role in the prosodic systems of Akan and/or whether it corresponds to the states of the root of the tongue [39].

5. Conclusion

The paper investigated the vowel quality of final vowels in string-identical YNQs and statements in Akan, a Kwa languages classified as belonging to the group of lax prosody languages [1], [2]. Results have shown that besides expected utterance-final effects that YNQs do not terminate breathier than statements and that the final vowels of YNQs are articulated with more speech effort, corroborating observations by [8] and [12]. It can thus be concluded that the non-H-pitched characteristics of Akan questions, sharply falling F0 and final lengthening, are not the result of laryngeal relaxation. Akan is not a lax prosody language.

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7. References

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