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دراسة صوتية لجزئيات الشفرة na و nãفي سياقهما الكلامي

An acoustic study of kode particles na and nã in their speech context

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ملخّص

تتميز لغة باولي-كودي، وهي لهجة من لغات باولي تنتمي إلى عائلة لغات كوا، بوجود جسيمين يظهران بشكل منتظم في معظم الجمل: جسيم الإضافة "نا na" وجسيم النفي "نا nã ". ويُشكل هذان الجسيمان في باولي-كودي تحديًا في التعرف على الجمل وتفسيرها. ونظرًا لهذا التحدي، نقترح دراسة صوتية تعتمد على معايير النبر (التردد الأساسي F0، والمدة، وترددات الرنين للأصوات المتحركة، وترددات الرنين لعرض النطاق) للتمييز بوضوح بين هذين الجسيمين. وتشير النتائج إلى أن التردد الأساسي F0 هو العامل الرئيسي في التمييز بين هذين الجسيمين في الكلام.

الكلمات المفتاحية: المدة؛ ترددات الرنين لعرض النطاق؛ التردد الأساسي F0؛ الجسيمات؛ ترددات الرنين لحروف العلة.

ABSTRACT

Baule-Kode, a variant of the Baule language belonging to the Kwa family, has two particles that systematically occur in most sentences: the additive particle na and the negative particle nã. Moreover, those particles in Baule-Kode pose the problem of sentence recognitions and interpretations. Given the problem of sentence recognition and interpretation due to the use of the particles in speech sentences, we propose an acoustic study based on the prosody parameters (fundamental frequency F0, duration, vowel formants, and formants of the bandwidth) to make a clear-cut difference between these particles. The results indicate that, among the prosody parameters, the fundamental frequency F0 is the key factor for distinguishing between the particles in speech.

Keywords: duration; formants of the bandwidth; fundamental frequency F0; particles; vowel formants.

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1. Introduction

1.1 The problem

distinction between the nasal and oral vowels, but their distributions are not entirely contrastive. In the coda position, a nasal vowel and a nasal consonant do not occur together. The vowel is only analyzed if the nasal characteristic of the nasal coda spreads to the left up to the nucleus; when the nasalization undergoes the phonology process, the nasal coda is lost (Timyan, 1975, 1977). As a universal constraint phenomenon via the mechanism of speech, phonetic nasalization can occur near nasal consonants (Cohn, 1993; Ladefoged, 1996; Ladefoged & Maddieson, 1996).

This study investigates whether form nasal and oral vowels in nasal contexts are truly distinguishable or whether their distributional constraints are purely phonological (Chung, 1996). Would the opposition between oral and nasal vowels be apparent through the particles "na /nã" Kode, despite their different meanings? In Kode, N = nasal consonant is underlying in the syllable CVN. It is realized in the of a surface CṼ. The ṼN form is a phonological constraint.

The phonological explanation will base on the research findings on nasals in many languages. Chung (1996) argues that in a nasal domain, the onsets and nuclei form one domain and the codas form another domain entirely. Ang (2002) contested the division of a syllable into two domains that Chung had made with evidence of trans-syllabic nasal diffusion, which presupposes the nasal propagation from nucleus to coda. He used constraint ranking in optimality theory to account for nasal propagation anomalies that were not well explained by previous phonological rules.

However, as Chung suggests, confirming these phonological patterns involves carrying out acoustic experiments to determine the extent to which the acoustic phenomena removes ambiguities in the production of these particles. Perhaps phonemic nasalization (i.e., nasal

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vowels in underlying forms) and phonetic nasalization (i.e., oral vowels in underlying forms that undergo a nasalization process due to context) are distinguished. That is, if the nasality between nasal vowels and nasalized oral vowels differs significantly from that of native speakers, the phonological analysis in the literature can be maintained. Otherwise, the vowel in NṼ *nã* can very well be treated as a "true" nasal vowel, and the vowel in NV *na* can very well be treated as an oral but nasalized vowel. It should be noted that in Kode there is a contrast between the oral vowel /a/ and /ã/. The list of some contrast words in (1) :

(1)

a.	*sřa* “moon”	vs.	*sřã* “human being”
b.	*ta* “ bring up”	vs.	*tã* “flatulate”
c.	*jřa* “get down!”	vs.	*jřã* “stop!
d.	*fja* “hide!”	vs.	*fjã* “speed up!”
e.	*kpa* “sort out!”	vs.	*kpã* “Cry!”
f.	*wa* "here”	vs.	*wã* “who”
g.	*ka* “Bite!”	vs.	*kã* “speak!”
h.	*ma* “grain”	vs.	*mã* “negation”
i.	*swa* “house”	vs.	*swã* “Support!”

(2) a. *Abo ku)) akO ni)* ***na*** *amu) di*

Abo kill chicken SPEC and you eat

“Abo kill the chicken and you eat”

b. *Abo ku)) akO ni)* ***nã*** *amu) di*

Abo kill chicken SPEC NEG you eat

“Abo kill the chicken you do not eat”

This study used acoustic data to study the contrast between the na and nã particles in the Kode discourse. It is based on the different vowels [a] and [ã] of our

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particles na and nã, respectively, in Kode. The general objective is to test whether Kode speakers can produce a clear distinction between these two vowel classes.

1.2.Hypotheses

According to the principle of percolation, if a segment in a domain is nasal, then the other segment in the same domain must be nasal too. What is the acoustic characteristic of the particles na and nã, where one is a coordinating conjunction (and) and the other is a negative particle? The particle na will be assigned as the coordinating conjunction, and nã as the negative particle. Prosody has a positive effect on the understanding of na and nã in kode particles. The paper assumes that "prosody" is operationally defined as "F0, duration, vowel formants, and formant bandwidths"; "understanding" is operationally defined as "levels of disambiguation and discrimination"; and "participant" is defined as "in a given situation." What are the chances of proving that the observed particle nã is different from na considering the duration, pitch, and the formants of the bandwidth of each vowel [ã] and [a]?

The following hypotheses are formulated: (1) The particles na and nã show significant acoustic differences in vowel duration. (2) The particles na and nã, through their different vowels, exhibit significant acoustic differences in the resonance frequency of the formants' bandwidth (BW). That is, the nasal vowel [ã] of the particle nã is greater than the oral vowel [a] of the particle na according to Chen (1995, 1997) and Pruthi (2007). (3) The particles na and nã, through their different vowels, have significant acoustic differences at the level of the vowel formants. (4) The particles na and nã, through their different vowels, exhibit significant acoustic differences in the fundamental frequency (F0).

2. Literature Review

Many phoneticians have noted that nasality affects vowel acoustics, with F1 values of high vowels being lower than those of oral vowels without nasal coupling. A nasal vowel is produced by the lowering gesture of the velum, which establishes an acoustic coupling between the oral and nasal passages. In the literature on nasality, it is generally accepted that the decrease in amplitude and enlargement of the first oral formant indicate a nasalization of vowels.

To characterize the acoustic features of the nasal vowel and nasalized vowels, Feng & Castelli (1996) suggested that vowel nasalization may be considered a dynamic trend from an oral configuration to the pharyngonasal configuration,

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with nasal vowels nasalized at a given time of the continuum and "true" nasal vowels at the end. Oral-nasal coupling has a number of acoustic consequences, including the addition of "null pole pairs" to the vowel spectrum and corresponding changes in frequencies, intensities, and bandwidths of oral formants (Beddor, 1993, p. 172).

The nasal vowels are distinct from the point of view of the articulation in that they involve a systematic lowering of the velum, thus allowing the air to circulate through the oral and nasal cavities. Each of these resonance cavities is associated with its own formant/spectral profile, which results in acoustic coupling of the oral and nasal pathways, which Krakow et al. (1988) and Maeda, 1993) called "oro-nasal coupling." In Kode, as in other Kwa languages, the phonological and phonemic status of the nasal segments is highly controversial.

The controversy goes from the diachronic process that gave birth to the nasal or nasalized vowels to questioning the phonemic status of these vowels. Capo (1981, 2010) and Williamson (1973) assert that the nasal vowels are phonemic in the Kwa languages, while Quaireau (1978, 1981) and Stahlke (1971a, 1971b) consider these vowels to be phonetically nasalized.

Phonetically nasalized vowels are obtained by the rule of nasal assimilation. That is, a vowel nasalizes when following a nasal consonant, /m/, /n/, or /ɲ/.

Until now, we have noticed that no acoustic research on the nasalization in Baule or in Kode has been performed. Nonetheless, we highlight a noteworthy finding from Konan et al.'s (2016) study on vowel-consonant phoneme detection. They offer in their study a phoneme separation algorithm, based on the difference in the energy levels of consonants and vowels. They also offer an algorithm of recognition by analyzing the formants. Pan (2004) investigated the airflow of oral vowels in nasal contexts (preceded or followed by nasal consonants) and found that only the onset or shift of oral vowels was nasalized, but not the center of vowels. She asserted that the absence of nasality at the mid of the oral vowel is the strategy used by the speakers to distinguish between nasal vowels and oral vowels in nasal contexts. This study used acoustic data to investigate the contrast between the particles na and nã in the Kode discourse.

In this study, the phonetic achievements of the two particles, with an emphasis on their respective vowels, will be compared. Since these particles have separate meanings, they should have completely different phonological structures, such as na contrasting with nã. This will allow to understand their different achievements in sentences. Indeed, the use of these particles in the Kode sentence creates

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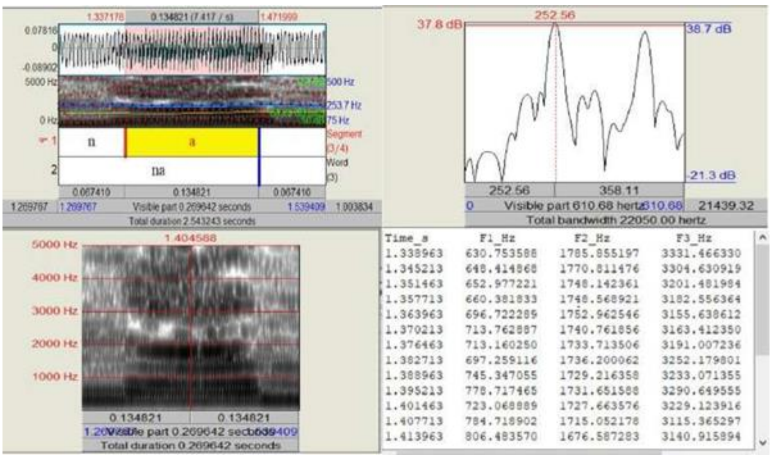
ambiguity if we adhere to Nespor & Vogel's (1983, 1986) definition of "ambiguous," which describes phrases that consist of identical sequences of words or sound segments with different meanings.

3. Acoustic analysis

Acoustic analyses were conducted with the Praat (Boersma & Weenink, 2017) software. The vowels were manually segmented, and then the first three formants were measured first manually and then automatically over the entire duration of the vowel. Next, the average F0 and vowel duration for all particles were measured. Finally, many values of the measurements, including duration, formants, and pitch, were extracted at different levels: specifically, for the entire vowel and for half of the vowel.

The corpus consists of a total of 866 vowels. Among these, 436 vowels were generated from the na particle, while 430 vowels were produced from the nã particle in each group. The values were collected in hertz, but also in semitones regarding the extraction of the pitch data. It is a more relevant scale because it respects the perception of frequencies by the human ear. Henton (1989) performed this Hertz-to-semitone conversion on data from several previous articles, as well as data collected by its care during its study. Statistical analyses with the linear model of regression and the t-test of the Satterthwaite method were performed for all measurements obtained with a probability, $p \leq .01$.

Figure 1



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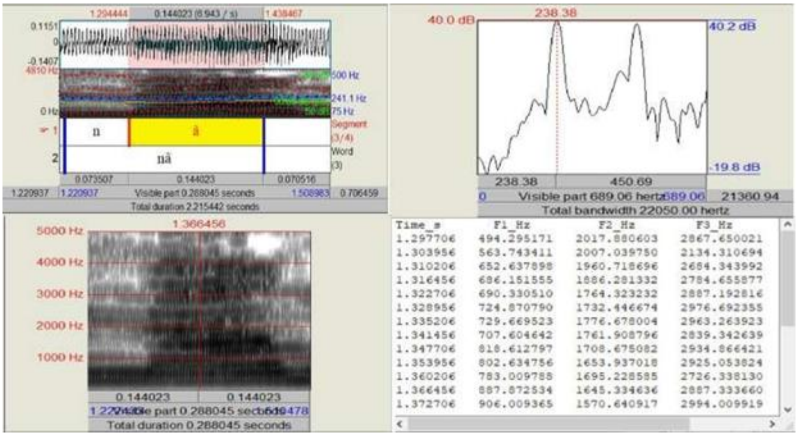
Source: Representation of the vowel [a] of the particle na produced by the speaker ad- AG-f-01-1, in the software praat. The upper left of the figure includes the textgrid of the particle whose spectrum corresponds to the selected part (in pink on the sound wave) is visible at the top right and the values of F1, F2, F3 detected by Praat for the same part of the vowel appear in the window at the bottom right. The lower left side the spectrogram with red the formants detected by praat.

Figure 2



Source: Representation of the vowel [ã] the particle nã produced by the speaker ad-AG-f- 01-1, in the software praat. The upper left of the figure includes the textgrid of the particle whose spectrum corresponds to the selected part (in pink on the sound wave) is visible at the top right and the values of F1, F2, F3 detected by Praat for the same part of the vowel appear in the window at the bottom right. The lower left side the spectrogram with red the formants detected by praat.

4. Methodology

4.1. Participants

Twenty participants (10 men and 10 women), all native speakers of Kode, participated in the recordings. The recording took place in the Department of Béoumi, precisely in the village of Assengou. The average age is 37. Among the subjects, some have school levels and others do not. They have an increased knowledge of the Kode language, and they live in the village.

4.2.Materials and procedures

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The test sentences were recorded by group. A series of 10 sentences with the na (ad) particle was read by the participants. Then another set of 10 sentences with the negative particle nã (ne) was also read. To avoid artificially influencing the prosodic segmentation of sentences, no instruction was given to the speakers as to how to read or phrase the stimuli. Participants were asked to produce Kode sentences corresponding to the French contexts provided. Indeed, participants were given sentences that included the particle notifications. This survey was conducted with an Olympus LS-P1 digital dictaphone between native speakers.

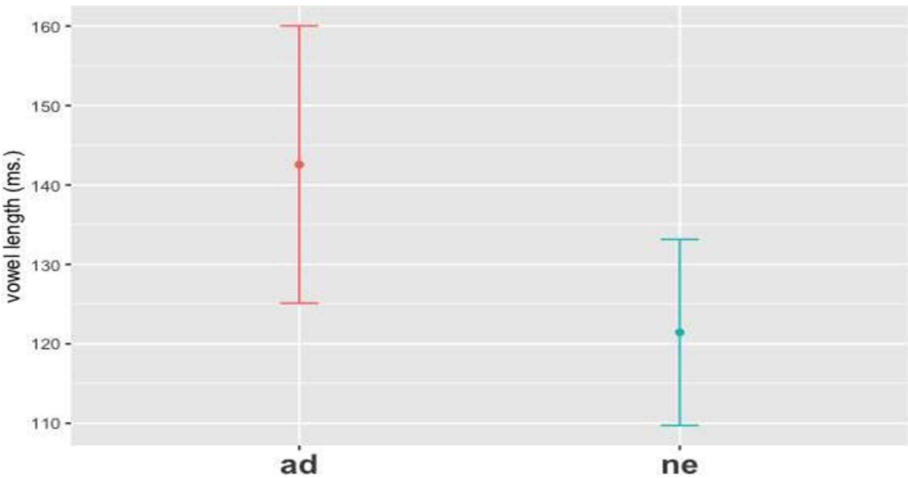
5. Results

In this part, we present the results of the acoustic analysis of the different vowels from our particles na and nã. The first sub-section is devoted to the values of the duration, the second to the formants, the third to the formants of the bandwidth (in this case, the first forming of the bandwidth, FBW1), and the last to the fundamental frequency (F0).

5.1. Analysis of vowel durations

The duration of each vowel has been studied by the speaker. This is the extracted average, which gives us the graph below (Figure 3). We call "ad" the particle addition na and "ne" the negation particle nã.

Figure 3



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Source: The duration of the vowels of the particles na (addition) and nã (negation) in milliseconds (ms).

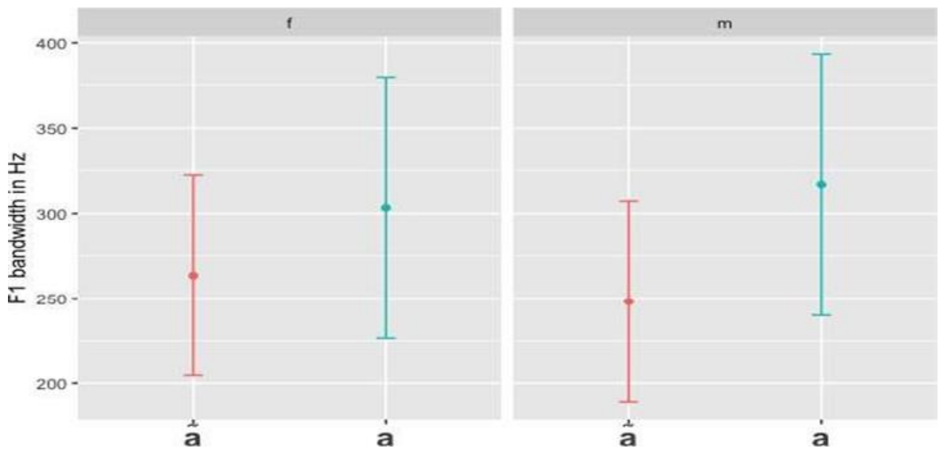
Figure 3 gives us a comparison of the duration of oral vowel /a/ and nasal /ã/ of different particles na and nã. This comparison shows that the median duration of the vowel /a/ of the na particle is greater than that of /ã/, 20 ms. The vowels of the particles na and nã present differences in significant durations, but this difference is only carried by the vowel /a/, which has the effect of lengthening the duration of the vowel (Figure 3, in red). This analysis shows a significant overall effect of the vowel of the particles over the duration, $p < .001$.

There is therefore a difference between the vowels of the particles, $p < .05$. When Kode speakers pronounce the particle na, the oral vowel [a] and nasal vowel [ã] durations in nã-containing sentences are different. For the particle na (ad), the average of the time left is as follows: 125 ms at the lower level, 143 ms for the median, and 160 ms at the upper level. As for the particle nã (ne), the measure of 110 ms at the lower level, 121 ms for the median, and 133 ms for the upper level.

5.2. Bandwidth Formant Analysis (F1BW)

The acoustic feature mainly considered in our analysis is the bandwidth of the first formant (F1 bandwidth).

Figure 4



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Source: The F1 bandwidth in Hertz (Hz) of the vowels according to the man and the woman.

Figure 4 gives us the different configurations (male/female) of the vowels [ã] and [a], respectively, of the na and nã particles. This allows us to say that the F1 band of women is high for the nasal vowel [ã], unlike the oral vowel [a], which records a higher band for men than for women. In both cases, the nasal vowel [ã] is smaller than the oral vowel [a] with a marginal effect, $p < .10$. This analysis indicates a significant overall effect of vowel type on F1 bandwidth. There is a significant effect between the "vowels of particles" and "F1 bandwidth factors, $p = .05$.

The F1 bandwidth of each vowel is therefore significantly higher, with a difference that remains stable from one type of vowel to the other. The sex variable is not significant because its value is greater than 0.5, $p = .7$. We record for the vowel /a/ as the mean of the median 330 Hz for men versus 301 Hz for women. The vowel [ã] has an average of the median of 250 Hz for men versus 270 Hz for women. These observations allow us to approximate the results of Delvaux et al. (2002, 2008) and Maeda (1993) on the degree of rounding, the degree of aperture of the mouth, and the earlier position of the nasal vowel than the oral vowel.

5.3.F2-F1 formant analysis

We conducted the statistical test, the linear regression model, to form the vowels of the particles. We calculated the difference between the F2 formant and the F1 formant. A measure taken at the center of the vowel.

Figure 5

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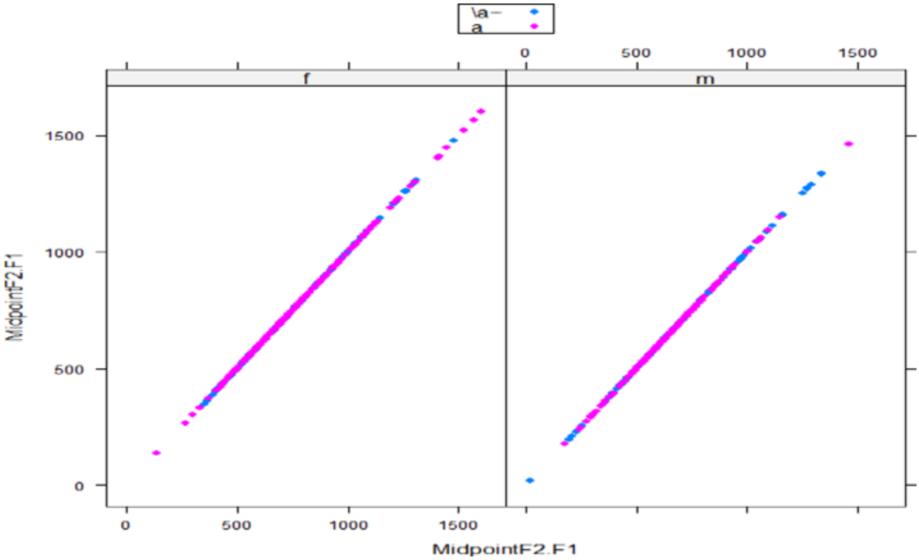

Source: The difference of formant F2-F1 in Hertz (Hz) of vowels according to man and woman.

The results showed that there are no significant effects between the vowels of the particles on the formant, $p > .05$. In addition, a significant effect is observed between the sex factor and the F2-F1 formant, with a $p < .05$.

No significant difference was found between the vowels of the two particles on the F2–F1 formant plane. Additionally, the "vowels" and "type of the speaker" do not significantly differ from one another, $p > .05$. The vowel [a] is significantly higher than that of [ã]. It is higher in women than in men. The important differences between women and men for the F1 of the vowel [æ] (Pépiot, 2013a, 2013b)are clearly observed.

5.4. Fundamental frequency analysis (F0)

The fundamental frequency (F0) is studied in two ways in semitones. The first concerns the fundamental frequency (F0) taken in the center of the vowel in semitones. The second concerns the whole vowel, always in semitones.

5.4.1 The F0 taken in the center of the vowel

A measurement of F0 taken in the center of the vowel allowed us to highlight the operation of the particles na and nã. The data collected comes from each speaker,

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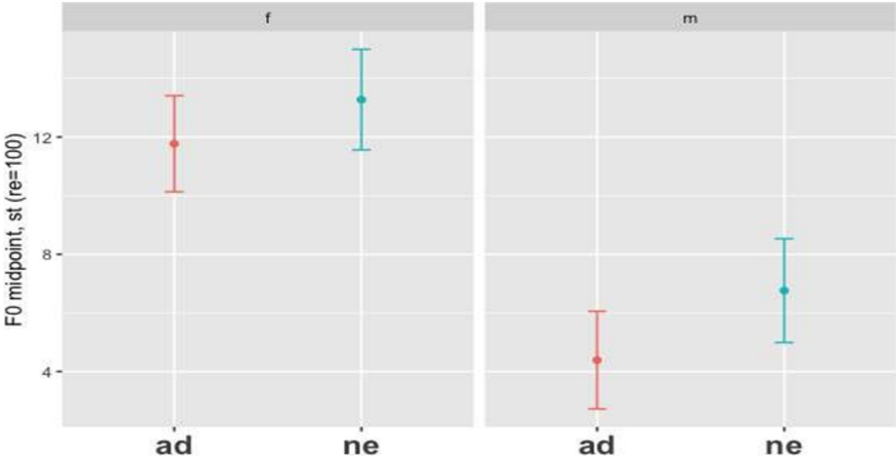
both at the level of women and men. The average of these measurements is given in Figure 6 through split graphs in two depending on the genre.

Figure 6



Source: The average of the fundamental frequency (F0) taken in the middle of each vowel.

Gender had a highly significant effect on fundamental frequency (F0) measured at the vowel center, $p < .0001$. The average fundamental frequency of women is therefore significantly higher than that of men in terms of particles. However, the effect of the particles on the F0 is significant, $p < .0001$. This means the F0 of the negative particle nã is significantly higher than the na particle. The fundamental frequency (F0) of the particles is generally higher in women than in men.

5.4.2 The F0 of the whole vowel

A measure of the whole vowel was taken also for each speaker in semitones. This allowed us to better understand the role of the fundamental frequency (F0) on the particles.

Figure 7

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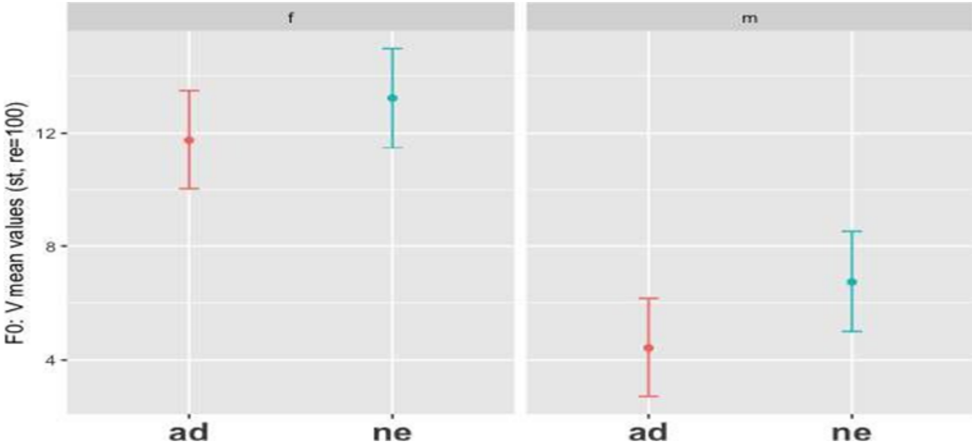

Source: The mean of the fundamental frequency (F0) of the vowels of the particles na (ad) and nã (ne) in semitones.

As expected, there is a highly significant effect of the genre on the average fundamental frequency (F0) of the vowel, $p < .0001$. This means that there is a correlation between the fundamental frequency of women, which is very high, and the fundamental frequency of men, which is low on particles. On the other hand, the effect of the particles on the F0 is significant. This implies that the F0 of the negative particle nã is significantly higher than the na particle.

6. Discussions

The acoustic analysis carried out in this paper, dealing with the production of na and nã particles by native Kode speakers, has allowed us to highlight several intriguing results, which should be synthesized, interpreted, and put into perspective.

6.1.Duration analysis

The comparison of the results to existing studies, according to several sources, shows that in many languages, nasal vowels are longer than oral vowels in all positions (Delattre & Monnot, 1968; Delvaux, 2009; Ruhlen, 1975; Greenberg et al., 1978). For example, in Twi (a language spoken in Ghana), nasal vowels are systematically longer than oral vowels (Manyah, 2011). This contradicts the analysis on the duration of the vowels [a] and [ã] in these particles. However, the oral vowel [a] is 20 ms longer than the nasal vowel [ã].

The oral vowel [a] was 20 ms longer than the nasal vowel [ã], contradicting previous findings (Duez, 2009; Jha, 1986; Lovatto et al., 2007; Manyah, 2011;

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Whalen & Beddor, 1989). Therefore, the duration is a powerful acoustic index to shed light on the difference between the particles na and nã - the addition particle and the negation particle, respectively. For this purpose, the hypothesis cannot be confirmed, which assumes that the particles na and nã, through their different vowels, have significant acoustic differences in duration.

6.2.Bandwidth Formant Analysis F1 (F1BW)

The results of the bandwidth (F1BW) show that there is a significant difference between the vowels of the particles depending on the bandwidth formant (F1BW). On the other hand, the genus has no significant interaction with the width of the band. The F1 bandwidth of the oral vowel [a] was higher than that of the nasal vowel [ã]. The energetic component (A1-P0) of the oral vowel [a] and nasal [ã] gives us an equivalence of their realization. The value of A1-H1 for oral vowels [a] and nasal [ã] takes a reversed direction. The bandwidth-forming (F1Bw) of the oral vowel is higher than the bandwidth-formant (F1BW). This is contrary to studies previously conducted on the value A1-H1 of the oral vowel [a] and the nasal vowel [ã].

The researchers have developed several acoustic correlates and parameters that can be used to characterize the nasal vowels of the oral vowel. Huffman (1990) found that A1-H1 (the difference in amplitude between F1 and the first harmonics) was correlated with the listener's perception of oral and nasal vowels. Huffman (1990) identified the mean difference between the amplitude of the first formant (A1) and the first harmonic (H1) and the variation of A1-H1 over time as good parameters to capture the decrease of A1 with the introduction of nasality.

Chen (1995, 1997) proposed two parameters combining the relative decrease of A1 with the emergence of the two nasal formants: A1-P0 and A1-P1 (differences in amplitude between F1 and the two nasal formants at about 450 Hz and 1 000 Hz, respectively), where P0 is the amplitude of the nasal formation inferior to F1 and P1 is the amplitude of the nasal formation above F1. As the nasality increases, F1 should decrease while P0 and P1 increase; thus, A1-P0 and A1-P1 should decrease with increased nasal coupling.

Indeed, Chen gives the characteristics of nasality. In this regard, he says that when the difference between the amplitude of the top of the first harmonic of F1 (A1) and the amplitude of the apex of the smallest harmonic of the nasal is higher than zero (A1-P0 > 0), we have in this case a nasality that is insignificant. When the difference between the peak of the first harmonic of F1 (A1) and the amplitude of

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the peak of the smallest harmonic of the nasal is equal to zero (A1-p0 $\approx$ 0), we have in this case an intermediate nasality.

Finally, when the difference between the amplitude of the first harmonic of F1 (A1) and the amplitude of the smallest nasal harmonic is lower than zero (A1-p0 < 0), we have a significant nasality. For this, we cannot give credit to our hypothesis H2, which says that the nasal vowel [ã] of the particle nã is greater than the oral vowel [a] of the particle na according to the resonance frequency of the bandwidth of the first formant (F1BW). This assumption is therefore not valid.

6.3.Analysis of Vowel formants F2-F1

In terms of vowel formants, we noted a significant effect of sex on the F2-F1 formant difference. As for the vowels of the particles, we see that they are equivalent. The analyses show that there is really no difference between vowels [a] and [ã] whatever the genre.

We have for women, 746 Hz for [a], 739 Hz for [ã]. As far as men are concerned, we have 635 Hz for [a] and 678 Hz for [ã]. The mean of the measured difference between the oral vowel [a] and the nasal vowel [ã] is insignificant, contrary to the values identified by Delattre & Monnot (1968), 250 Hz for the nasal vowel [ã] and 750 Hz for the oral vowel [a].

The hypothesis suggesting significant vowel formant differences between na and nã was not supported. The distinction between the particles na and nã does not rely significantly on vowel formants.

6.4.Analysis of the F0 in semitones

The results obtained from the analyses of the fundamental frequency (F0) in semitones at the center of gravity of the vowel and at the level of the whole vowel show us that in both cases the F0 has an effect on the particles na and nã through their respective vowels [a] and [ã]. In all cases, the fundamental frequency (F0) of the female speakers is significantly higher than that of the speaker. At the scale of the genus, it reaches a higher mean for the nã particle and a lower mean for the na particle.

These analyses confirm the studies of Fry (1979) and Miller (2007) on the effect of gender on the production of vowels. For Meunier, there is a variation due to the specificity of each speaker, its geographical origin, and its social characteristics. In general, it can be said that the pitch of the nasal vowel [ã] is greater than the pitch of the oral vowel [a]. The fundamental frequency mean measured for each

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particle gives us the following values: 165Hz for the addition particle and 225Hz for the negation particle.

Given these findings, it is reasonable to conclude that the negation particle nã is significantly more common than the na particle. Following the results of Aithal et al. (2012), reporting that the F0 values associated with production can range from 240 to 634 Hz for pitch, and Michel (1968), which indicates that the F0 values associated with the production of a low pitch can range from 30.7 to 43.7 Hz, we may argue that the negative particle receives a high pitch (225Hz) against 165 Hz for a low pitch for the addition particle.

The correlation tests (t-test) between the F0 measurements and the vowels of the particles show no clear interaction. This is consistent with the findings of Weirich & Simpson (2013, 1989). Weirich & Simpson predicted that women with higher voice heights would have a corresponding size of the larger vowel space; however, their findings did not suggest this research. They concluded that the size of the larger vowel space in women is not due to the need for sufficient contrast but rather to the consequence of the interaction of other factors.

Picanço (2005) uses acoustic analysis of vowels to show that the fundamental frequency F0 is more reliable in the quest for lexical contrast than vocal quality (e.g., Munduruku). It is clear that the fundamental frequency (F0) provides a credible auditory characteristic for identifying the tonal contrast between our two particles. Thus, the hypothesis that na and nã differ significantly in fundamental frequency (F0) is confirmed.

7. Conclusion

The problem was to identify the acoustic parameter that can account for the prosodic difference between two particles na and nã. To reach the goal, the work investigated some prosodic parameters: duration (ms), the formant bandwidth (Fbw), the vowel formant (F2-F1), and the fundamental frequency (F0). Among the tested parameters, fundamental frequency (F0) best distinguishes na from nã . In fact, the fundamental frequency calculated between the two genders shows that the negative particle nã is more prominent than na, particle of addition.

8.References

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