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Acoustic properties of bilabial trills in Medumba

Kenneth S. Olson [*]

Abstract. Olson (2022) claims that all bilabial trills in phonemic systems are releases of stops. They are either part of complex phonemes that involve stop-trill sequences, e.g. /p^{ʙ}, b^{ʙ}, ^{m}b^{ʙ}, t^{P}/, or they pattern as allophones of a compressed or fricative vowel following a stop, e.g. [pʙ̥, bʙ̥, tʙ̥]. Olson notes that the stop-trill phonemes behave as obstruents. I provide acoustic evidence for this claim.

Previous studies indicate that the closure of /b/ is shorter than that of /p, ^{m}b/ and that the oral portion of the closure of /^{m}b/ is very short (~30–40 ms). Likewise, it has been shown that the stop closure of /b^{ʙ}/ is shorter than that of /p^{ʙ}, ^{m}b^{ʙ}/ and that the oral portion of the stop closure of /^{m}b^{ʙ}/ is very short (e.g. Olson 2023). For Medumba (Cameroon), we find similar patterning. The mean stop closure durations of /b^{ʙ}, ^{m}b^{ʙ}/ are 137 ms (s.d. = 28, n = 58) and 192 ms (s.d. = 47, n = 28), respectively. The difference is very highly significant: $t(37) = 5.79$, $p < 0.001$ (one-tailed). The mean oral stop closure duration of /^{m}b^{ʙ}/ is 26.6 ms (s.d. = 6.2, n = 28).

The finding that stops with bilabial trill releases behave as obstruents is important, because elsewhere they have been categorized with /r/ assuming that they are sonorants.

Keywords. bilabial trills; prenasalization; release; speech timing; Narrow Grassfields; Medumba

1. Introduction. Bilabial trills are speech sounds found in about 70 languages. Clusters of languages with bilabial trills are found in Papua New Guinea, Vanuatu, Cameroon, China, the Democratic Republic of the Congo (DRC), South Sudan, and Brazil. Individual languages with bilabial trills are found in Indonesia, India, and Georgia (Keating 2007, Olson 2022).

Olson (2022) claims that all bilabial trills in phonemic systems are releases of stops. First, they can occur in complex phonemes where they pattern as the release of a stop. The stop that initiates the trill is usually bilabial, e.g. /p^{ʙ}, b^{ʙ}, ^{m}b^{ʙ}/, but it can also be coronal, e.g. /t^{P}/ (Ladefoged & Everett 1996, Coupe 2015),[1] or labial-velar, e.g. /kp^{ʙ}, gb^{ʙ}, ^{ŋ}gb^{ʙ}/ (Kutsch Lojenga 2013). Second, in some languages of China bilabial trills pattern as allophones of compressed or fricative vowels following bilabial and/or coronal stops, e.g. [pʙ̥, bʙ̥, tʙ̥].

In Cameroon, bilabial trills are attested in nine Bantoid languages: Medumba, Ngwe, Babanki/Kejom, Kom, Kuk, Mfumte, Mungaka, Oku, and Vute (Olson 2022 and references therein). All these languages are classified as Narrow Grassfields, except Vute which is Mambiloid. Bilabial stop-trill phonemes are attested in Medumba /b^{ʙ}, ^{m}b^{ʙ}/ and Ngwe /b^{ʙ}/. Bilabial trills are allophonic in the other languages. They are sometimes replaced by a fricative release.

Medumba (ISO 639-3 code: byv) is spoken by about 210,000 people in and around the city of Bangangte, Cameroon. Bilabial trills in Medumba were previously studied by Olson & Meynadier (2015), who examined the acoustics of the sounds for one speaker.

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[1] Olson (2022) incorrectly transcribes the Sangtam unaspirated stop-trill phoneme. The correct transcription is [tʙ].

The Medumba consonant inventory includes two phonemes with bilabial trill releases: /b^B, ^{m}b^B/. The following dataset demonstrates contrast: [bə́] ‘be’, [bʙə̀] ‘cola nut’, [mbə́.mə́] ‘kaolin’, [mbʙə̀] ‘first’.

Olson & Meynadier (2015) report on the duration of the oral stop closure and the trill period of the bilabial trill releases for one speaker of Medumba. However, they omitted measurements of the duration of the nasal portion of the stop closure in /^{m}b^B/. For their data, the modal number of trill periods is two. The voicing bar was present throughout the trill.

In this paper, I study a second Medumba speaker. I provide more complete measurements, including the duration of the nasal closure for /^{m}b^B/.

2. Methodology.

2.1. SUBJECT. A 26-year-old educated female native speaker of Medumba participated in this experiment. The subject lived in Yaoundé and had moved there in 2006, nine years before the experiment. She had completed her Master II. Besides Medumba, she also spoke French.

2.2. PROCEDURES. A list of 75 words spoken in isolation were recorded. These words were chosen to include bilabial trills and plain bilabial stops preceding the various vowels in the language.

The wordlist was recorded on February 4, 2015 at the SIL Cameroon Training Centre in Yaoundé. The subject was seated and read prompts on sheets of paper transcribed in the CEPOM orthography (Nana et al. 2011). The researcher produced the gloss for each word in French, and then the subject produced the corresponding word in Medumba two times.

The recording was made with a Zoom H2 recorder at a 48 kHz sampling rate and 24-bit quantization. The recordings were stored in non-compressed WAV format. The archival form is available for download (Olson et al. 2024).

2.3. ANALYSIS. Waveforms and spectrograms were examined using Praat (Boersma & Weenink 2022). Default parameters were used, except that the dynamic range of spectrograms was set at 50 dB.

First, the closure duration of the stop preceding the trill release was measured. For prenasalized stops, both the nasal closure (indicated by nasal formants) and the oral closure (indicated by a significant drop in signal amplitude) were measured.

Second, the number of trill periods (Maddieson 1989a) for each token was counted. For the speaker, the modal number of trill periods was two, but one trill period was nearly as common as two. In some tokens, a trill was expected but was not observed in the waveform or spectrogram. Instead, a period of frication usually occurred instead. Rangelov (2019) refers to these as failed trills, as opposed to successful trills.

Third, trill period duration was measured. The first trill period was defined as the time from the release of the stop closure to the release of the first trill closure (or partial closure), indicated by an increase in signal amplitude (Maddieson 1989a). Subsequent trill periods were defined as the time from the release of the trill closure to the release of the following trill closure.

Sample waveforms and spectrograms are given for /b^B, ^{m}b^B/ in Figures 1 and 2, respectively. A phonetic transcription is provided below each spectrogram, with segments demarcated where appropriate.

3. Results.

3.1. STOP CLOSURE DURATION. The mean duration of the stop closures for /b^B, ^{m}b^B/ are 137 ms and 192 ms, respectively, as shown in Table 1.

Phoneme	n	Closure duration ($\bar{x}$)	s.d.
/b^{B}/	58	137 ms	28
/$^{m}b^{B}$/	28	192 ms	47

Table 1. Stop closure duration measurements for /b^{B}, $^{m}b^{B}$/.
n = number of tokens, $\bar{x}$ = sample mean, s.d. = standard deviation.

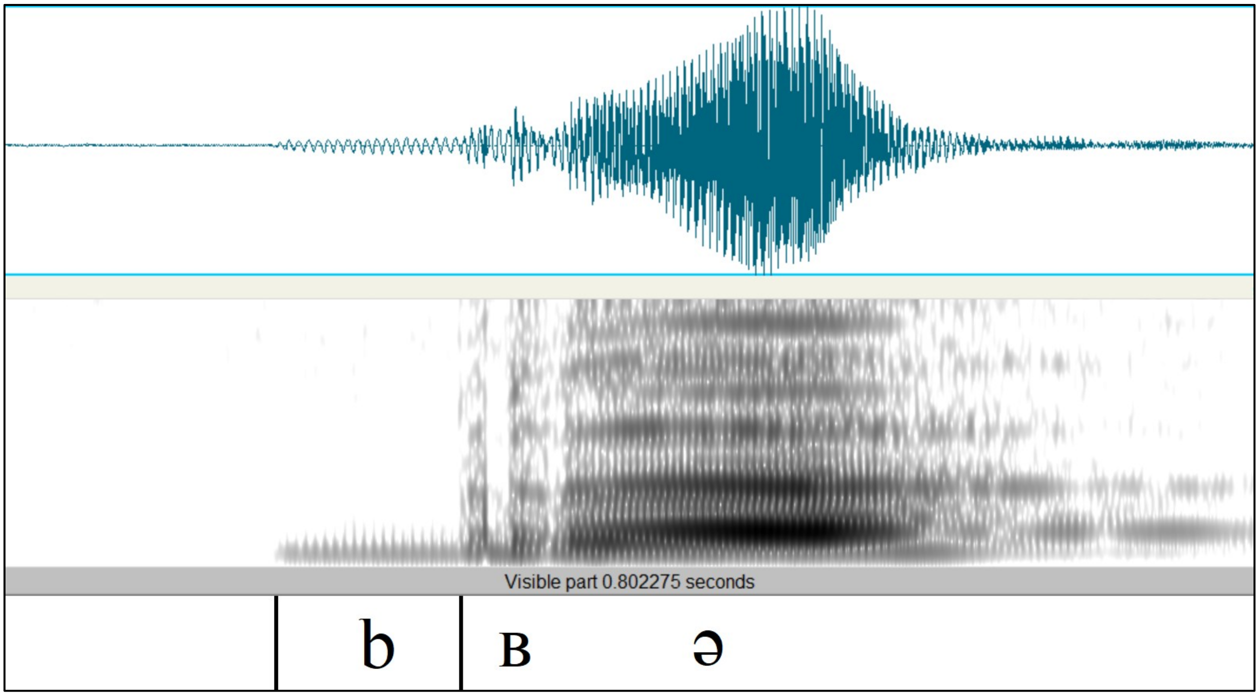

Figure 1. Waveform and spectrogram for [bʙə̀] ‘cola nut’

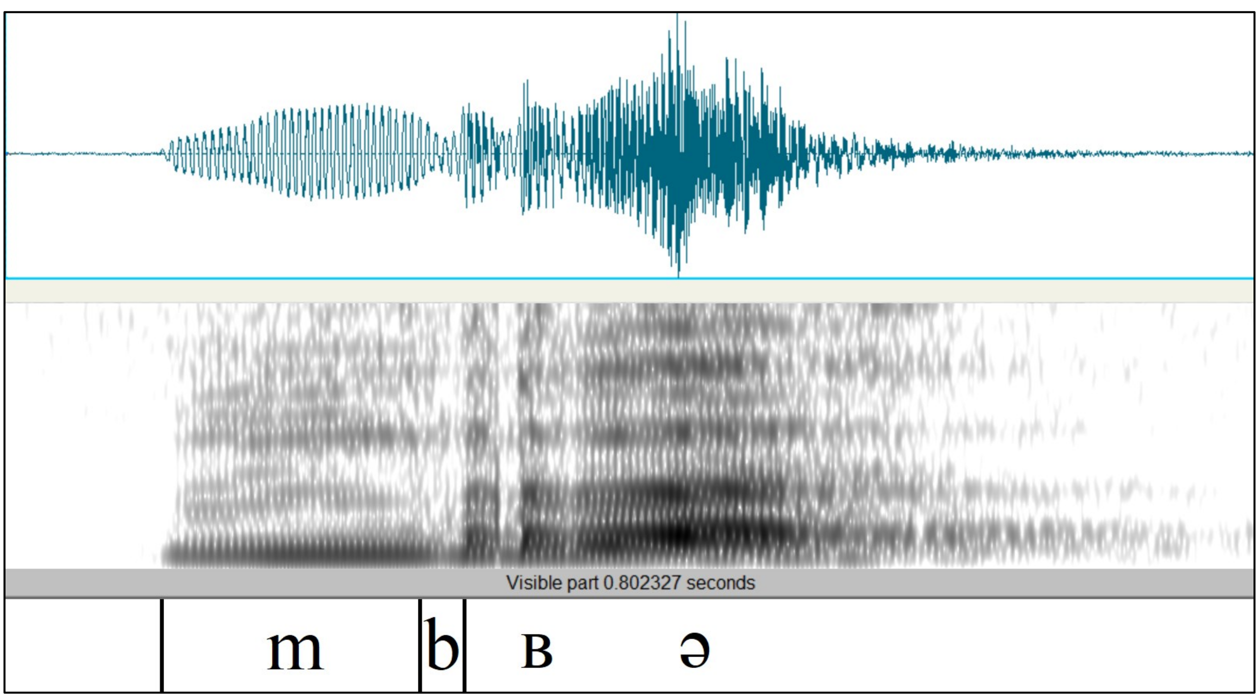

Figure 2. Waveform and spectrogram for [mbʙə̀] ‘first’

The difference in stop closure duration between /b^{B}/ and /^{m}b^{B}/ is very highly signficant: $t(37) = 5.79$, $p < 0.001$ (one-tailed).

This pattern, in which the stop closure duration of /b^{B}/ is significantly shorter than the stop closure duration of /^{m}b^{B}/, fits well with the previous research, in two ways. First, Olson (2023) found that in Mangbetu (DRC), the stop closure duration of /b^{B}/ was shorter than that of /p^{B}/ and /^{m}b^{B}/. Second, a similar pattern has been noted for the plain bilabial stops /p, b, ^{m}b/. Olson (2005) noted that the closure duration of /b/ is shorter than that of /^{m}b/ in Mono (DRC). Lisker (1957) observed that the closure duration of English /b/ is shorter than that of /p/ in intervocalic position. Maddieson (1989b) found that the closure duration of /p/ and /^{m}b/ are similar for Fijian.

For /^{m}b^{B}/, the mean duration of the nasal portion of the stop closure is 165 ms (s.d. = 48, n = 28), and the mean duration of the oral portion of the stop closure is 26.6 ms (s.d. = 6.2, n = 28).

This short oral closure for /^{m}b^{B}/ is well attested elsewhere (Maddieson 1989a, Olson & Meynadier 2015, Rangelov 2019, Olson 2023), and a short oral closure has been documented for /^{m}b/ as well (Maddieson 1989b, Olson 2005). In other words, the short oral closure of /^{m}b^{B}/ does not appear to be novel but is rather consistent with prenasalized stops in general (Ladefoged & Maddieson 1996).

For both /b^{B}/ and /^{m}b^{B}/, voicing is maintained throughout closure for all tokens. This is the same as what Olson & Meynadier (2015) found for their Medumba speaker. However, this differs from Olson's (2023) findings for Mangbetu, in which voicing attenuated completely before the end of the closure in almost half of the tokens. More research is needed to determine if this difference is the result of the individual speakers, or the result of the different languages.

3.2. NUMBER OF TRILL PERIODS. The number of trill periods varied from zero to five in my data. Out of 86 tokens, 23 had one trill period, 25 had two trill periods, 10 had three trill periods, two had four trill periods, and one had five trill periods. Hence, the modal number of trill periods was two, but there were nearly as many tokens with one trill period. Previous research suggests that two modal trill periods is most common for bilabial trills, e.g. Kurti, Na?ahai, Uripiv, Ahamb (Maddieson 1989a, Rangelov 2019), but languages with one modal trill period are also attested, e.g. Ngwe, Mangbetu (Maddieson 1989a, Olson 2023).

The remaining 25 tokens had zero trill periods, i.e. these were failed trills. Previous studies (Maddieson 1989a, Ladefoged & Everett 1996, Yoder 2010, Rangelov 2019, Olson 2023) have shown that bilabial trills often do not occur when they are expected to do so, and this is also the case for Medumba. In these cases, a period of frication is usually observed.

Eighteen of the failed trills occurred before the vowel /i/. This appears to be a feature of this study's speaker, as all her bilabial trills failed before /i/. In contrast, the speaker in Olson & Meynadier (2015) regularly produced bilabial trills before /i/.

Tables 2 and 3 show the number of trill periods for /b^{B}/ and /^{m}b^{B}/, respectively, broken down by the following vowel. In my data, /^{m}b^{B}/ has a higher percentage of successful trills (75%) compared to /b^{B}/ (69%). This is also the case if the tokens with a following /i/ are removed from consideration (95% vs. 87%). On the other hand, /b^{B}/ has a slightly higher percentage of tokens with two or more trill periods (45%) compared to /^{m}b^{B}/ (43%). This is also the case if the tokens with a following /i/ are removed (57% vs. 55%).

The trilling of /b^{B}, ^{m}b^{B}/ is most robust before the central vowels /ʉ̹, ə/[2] in Medumba. The percentage of successful trills before these vowels is 93% compared to 83% before the back

[2] For a description of the vowel [ʉ̹], see Olson & Meynadier (2015).

vowels /u, o, ɔ/. Also, trills before central vowels have two or more trill periods 68% of the time, whereas before back vowels, the percentage drops to 33%.

	n	0 t.p.	1 t.p.	2 t.p.	3 t.p.	4 t.p.	5 t.p.
/b^{B}i/	12	12	0	0	0	0	0
/b^{B}ʉ̜/	10	2	0	3	4	1	0
/b^{B}ə/	16	0	5	6	3	1	1
/b^{B}u/	6	1	4	1	0	0	0
/b^{B}o/	8	1	3	3	1	0	0
/b^{B}ɔ/	6	2	2	1	1	0	0

Table 2. Number of trill periods per token for /b^B/ before various vowels.
t.p. = trill period.

	n	0 t.p.	1 t.p.	2 t.p.	3 t.p.
/^{m}b^{B}i/	6	6	0	0	0
/^{m}b^{B}ʉ̜/	10	0	3	7	0
/^{m}b^{B}ə/	8	1	3	3	1
/^{m}b^{B}u/	0	0	0	0	0
/^{m}b^{B}o/	4	0	3	1	0
/^{m}b^{B}ɔ/	0	0	0	0	0

Table 3. Number of trill periods per token for /^{m}b^B/ before various vowels.

3.3. TRILL PERIOD DURATION AND FREQUENCY RATE OF TRILLING. The duration of the first trill period for /b^B, ^{m}b^B/ is shown in Table 4. The corresponding frequency rates of trilling are shown as well.

Phoneme	n	t.p. duration ($\bar{x}$)	s.d.	frequency ($\bar{x}$)	s.d.
/b^B/	40	30.1 ms	6.3	34.5 Hz	6.8
/^{m}b^B/	21	32.1 ms	5.2	32.0 Hz	5.2

Table 4. Duration and frequency rate of trilling of first trill period for /b^B, ^{m}b^B/.
Failed trills are excluded.

Previous studies have reported trill period durations ranging from 31–56 ms (Ladefoged, Cochran & Disner 1977, Maddieson 1989a, Demolin 1990, Olson & Meynadier 2015, Rangelov 2019, Olson 2023). The results of the present study are at the lower end of this range.

4. Discussion. In Section 3.1, I pointed out that there is a similarity in timing between plain bilabial stops and stops with a bilabial trill release. Specifically, the stop closure duration of /b, b^B/ is significantly shorter than that of /p, p^B, ^{m}b, ^{m}b^B/ (Maddieson 1989b, Maddieson & Ladefoged 1993, Olson 2005, Rangelov 2019, Olson 2023). In addition, the *oral* stop closure duration of /^{m}b, ^{m}b^B/ is very short, in the range of 30–40 ms (Maddieson 1989b, Olson 2005, Rangelov 2019, Olson 2023). We have seen that both observations also hold for Medumba.

This adds to the evidence that stops with a bilabial trill release behave as obstruents rather than as sonorants. As mentioned in the introduction, Olson (2022) provided evidence that *all* known cases of bilabial trills in phonemic systems are of this type: they involve a stop released into a bilabial trill.

This finding is important, because bilabial trills are sometimes categorized with /r/ under the assumption that they are sonorants (e.g. Rangelov et al. 2023). Since phonemes with bilabial trills behave as obstruents, this assumption is unwarranted.

A second finding of this study is the confirmation that the CEPOM orthography (Nana et al. 2011) is appropriately suited to the Medumba sound system regarding the stops with a bilabial trill release. Table 5 shows the co-occurrence of /b, b^{B}/ before the various vowels in the language. Before the high vowels /i, ʉ̜, u/ there is a neutralization of contrast between /b/ and /b^{B}/ in favor of /b^{B}/. Before /ə, o, ɔ/ there is contrast between /b/ and /b^{B}/. Before /ɪ, ɛ, a ɑ/ the trilled release is not attested.

Vowel	/b^{B}/	Gloss	#	/b/	Gloss	#
/i/	[bβí]	knife	16, 26	—		
/ʉ̜/	[bʙʉ̜́n]	milk	20	—		
/u/	[bʙú]	hand	63	—		
/ə/	[bʙə̀]	cola nut	5, 50	[nə̀ bə́]	to be	15, 52
/o/	[bʙóŋ]	poverty	9, 66	[bó.ò]	two	O&M
/ɔ/	[bʙɔ̌]~[bβɔ̌]	good	8	[bɔ̀.lí]	bra	73
/ɪ/	—			[bə́.bí.lá]	caterpillar	33
/ɛ/	—			[bɛ́.nə́]	straw	38
/a/	—			[bá]	bicycle	55
/ɑ/	—			[bɑ̀b]	wing	41

Table 5. Sample lexical items showing /b^{B}/ and /b/ before various vowels.
= item number in Olson et al. (2024). O&M = Olson & Meynadier (2015).

These observations can be summarized as shown in (1):

(1) Phonological status of [bʙ, mbʙ] in Medumba
a. /b, ^{m}b/ → [bʙ, mbʙ] / __ /i, ʉ̜, u/
b. /b, ^{m}b/ contrast with /b^{B}, ^{m}b^{B}/ before /ə, o, ɔ/
c. [bʙ, mbʙ] are not attested before /ɪ, ɛ, a, ɑ/

The conventions for writing [bʙ, mbʙ] in the CEPOM orthography (Nana et al. 2011), shown in (2), harmonize well with the phonological behavior of the sounds:

(2) Conventions for writing [bʙ, mbʙ] in the CEPOM orthography
a. < b, mb > are written before < i, ʉ, u > to represent [bʙ, mbʙ],
b. < bw, mbw > are written before < ə, o, ɔ > to represent /b^{B}, ^{m}b^{B}/.

A third takeaway from this study is that phonological generalizations become clearer by working with more than one speaker. The speaker in Olson & Meynadier (2015) produced bila-bilabial trills before /i/ but not /u/, whereas the speaker in this study produced bilabial trills before /u/ but not /i/. In both cases, the failed trills were replaced by frication, but the phonological generalization became clearer by considering both speakers. Ladefoged (2003) recommends testing at least a half-dozen speakers of each sex.

There is much room for future work on bilabial trills in Medumba. This includes:

- Testing more speakers, per Ladefoged's (2003) recommendation,
- Comparing the stop closure duration of the phonemes with trilled release with their non-trill counterparts,

- Using earbuds to measure more precisely the nasal stop closure of /ᵐbᴮ/ (Stewart & Kohlberger 2017, Rangelov 2019), and
- Making video recordings to study lip oscillations, in particular seeing if they are present even if they were not detected in the spectrogram (Rangelov 2019).

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