Acoustic properties of implosives in Bantu Mpiemo

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Abstract

Previous studies on implosives have shown a great diversity in the production of implosives among the languages in the world. In the light of this, this paper seeks to identify the acoustic phonetic properties of a Bantu language, Mpiemo, spoken in the Central African Republic. One of the strong acoustic correlates of implosives is increasing voicing amplitude during occlusion, which contrasts with a decreasing voicing amplitude for voiced plosives. Another acoustic property of implosives is the increased F0 during the occlusion, which continues all the way to the end of the following vowel.

Introduction

Understanding the exact phonetic nature of implosives and alike is important not only for phoneticians but also for linguists who attempt to explain various linguistic phenomena with reference to phonetics. One of the findings among the previous studies on implosives is a great diversity in the production of implosives. Such variability can be language specific, speaker specific, and even token specific (Lindau 1984, Demolin 2002, Jessen 2002). Despite interests in these variations, studies on implosives are still extremely limited compared to those on plosives. This paper presents a qualitative description of the acoustic phonetic properties of implosives and voiced plosives in Mpiemo, a Bantu language spoken in the Central African Republic. A more complete description with a quantitative analysis of the acoustic parameters is under preparation.

Implosives in Mpiemo

Implosives are found quite commonly among the Bantu languages, be that as allophones or separate phonemes. In the early description of Mpiemo, implosives were analyzed as separate phonemes (Beavon 1978) but more recent analysis treats them as allophones of the counterpart voiced plosives (Thornell 2001, Thornell and Nagano-Madsen 2004). The two implosives [ɓ, ɗ] appear as allophones of /b, d/ in stem initial position where the following vowel is neither [i] nor [u], nor after a syllabic nasal. In stem medial position, it is usually realized as a fricative [β] or an affricate [dz]. All the nouns in Mpiemo start with a noun class prefix such as /a/ and /bi/ as in /abogi/ ‘wall’ and /bidigi/ ‘forests’. So in /abogi/, /b/ is stem initial but not word initial. In the following examples, plosives and implosives appear stem initially; the noun [ɗɛ̀yǐ] ‘chair’ has a ‘zero prefix’.

[[díβĩ] ‘to open’
[dèlĩ] ‘to bury’
[dɛ̀yĩ] ‘chair’
[dàyĩ] ‘to lift’
[dɔlɔ] ‘to pull’
[dɔyĩ] ‘to return’
[dùlĩ] ‘to follow’
[mbɛá] ‘to become cooked’

Mpiemo Vowels

Figure 1 shows formant means for the seven vowel phonemes in Mpiemo. The two high vowels /i, e/ and /u, o/ are very close to each other both auditorily and in their formant values.

![Figure 1. Mpiemo vowel formant means. Each point represents 16 tokens for four speakers in (near) minimal pairs.](image)

Data and analysis

Based on the sound system of Mpiemo described in Thornell and Nagano-Madsen (2004), word lists containing [b, d] and [ɓ, ɗ]
both stem initially and medially in an analogous environment were prepared. The word in question was produced twice in isolation and once in an embedded sentence. Recordings of four male native speakers of Mpiemo were obtained in the town of Nola in the Central African Republic by the second author. A total of 960 sample words were obtained. The recorded data was analyzed using PRAAT and SUGI Speechanalyser.

## Results

The acoustic phonetic properties of the voiced plosives and implosives in Mpiemo will be described qualitatively with reference to a number of parameters that emerged from the previous studies on implosives. Figures 2 (a, b) show waveform, F0, wideband spectrogram, and intensity for [d] and [ɗ] in utterance initial position for two speakers. Figures 3 (a, b) show waveform of [b] and [ɓ] in intervocalic position for two speakers.

### Voicing

Even though implosives are most typically ‘voiced’ because of their production mechanism, the variability in voicing across languages in the production of implosives has been pointed out. In Xhosa, a Southern-Bantu language spoken in South Africa, only implosives are fully voiced while phonologically ‘voiced’ plosives are much closer to a voiceless plosive than a voiced plosive, percentage of voicing being below 20% and lower than those reported for English and German (Jessen 2002).

Our data of Mpiemo suggests that both implosives and voiced plosives are fully voiced unless spoken very slowly (in that case, the early part of occlusion is voiceless), and there was no cross-speaker variability on this parameter.

### Voicing amplitude

Another area in which the production of implosives can vary across languages is voicing amplitude. Voicing amplitude, i.e. the amplitude of the vocal cord vibrations, can provide an indirect indication as to the state of vocal cord as well as the amount of cavity expansion in an implosive. Increasing voicing amplitude was typically associated with implosives while decreasing voicing amplitude was associated with voiced plosives. Voicing amplitude was a fairly consistent acoustic associate in differentiating implosives from voiced plosives in Mpiemo. These findings indicate that implosives and voiced plosives in
Mpiemo are characterized by the traditional view in which glottalic ingressive vs. egressive airflow is involved in the production of the two types of plosives. Note that more recent studies on implosives from various languages have claimed that this is not always the case (McLaughlin 2005).

In her study of glottalic consonants in Niger-Congo languages, Lindau (1984) writes ‘In the Niger-Congo languages implosive usually means a rapidly descending larynx with the vocal cords vibrating with tight closures at the beginning of the closure and continuing with more regular vibrations.’ However, Mpiemo data suggests there can be variation as to the state of glottis at the time of initiation of the ingressive airstream mechanism. Two of our speakers used tightly closed glottis such as reported by Lindau (cf. Figure 2 (a) and Figure 3 (a)) while for two other speakers, it looks different (cf. Figure 2 (b) and Figure 3 (b)). For the latter, it is indicative that the vocal only loosely come in contact to allow vibrations with large amplitude right from the onset of occlusion. This variation was found to be speaker specific and since the same type of manifestation was found both in the utterance initial position and intervocalic position, it is not a matter of contextual effect. In fact a more recent study states that implosives can be produced with modal voice, with a more tense voice setting, and with complete glottal closure (Ladefoged and Maddieson 1996:82). In Mpiemo, this point is attested as a speaker specific feature.

**Intensity**

Intensity showed a good correlation with voicing amplitude and F0 and it is higher/ increasing for implosives than for plosives.

**F0**

The most consistent difference between voiced plosives and implosives was that of F0 characteristics. During implosives, the F0 usually rise from the onset of occlusion and it can continue up to the end of the following vowel. For voiced plosives, on the other hand, the F0 shows no such increase but often shows a sharp dip. It should be noted that such effect on F0 should be compared under the same tone environment in order not to be diffused. The characteristics of F0 in differentiating voiced plosives from implosives appear to override the characteristics found in voicing amplitude.

Figure 4 shows F0 of the first syllable of the words [dɔyi] ‘to return’ and [dũi] ‘to follow’. The effect of plosives and implosives appeared differently on the F0 of the following vowel. During an implosive, the F0 constantly rises while it decreases for voiced plosives. The difference often continues all the way to the end of the following vowel. This can be examined further as a hypothesis with statistical treatment.

![Figure 4: F0 of the first syllable of the words [dɔyi] 'to return' and [dũi] 'to follow'. Speaker A.](image)

**Formant structure**

Visibility of formant structure occurred as a function of the large voicing amplitude, be that implosive or plosive. Therefore it cannot be attributed as a common property of implosives in Mpiemo.

**Implosion**

Implosives are often assumed to accompany implosion at the release but our data from Mpiemo suggests it is not a consistent phonetic feature of an implosive. It was indicative that the presence of implosion for implosives is speaker specific. If present, implosion is manifested by increased VOT, burst amplitude, or both. Within the same speaker, there were no notable token-to-token variations. Lindau (1984) conjectures that the high ration of amplitude indicates that it has the highest degree of implosion in her study of several Nigerian languages. In the present data, however, no such systematic relation was found between the amplitude ratio and implosion.

**Closure duration**

Voiced plosives [b, d] are in general shorter than their counterpart implosives [ɓ, ɗ] both in
utterance initial and medial positions. In our data from Mpiemo, cross-speaker variation in the occlusion duration was found to be a function of speaking rate. Figure 5 shows the mean duration of [ɗ] compared across speakers where the first speaker has the longest duration but the rest of the three speakers are similar in duration.

Figure 5. Speaker variation in the occlusion duration of [ɗ] at the intervocalic analogous environment. N=44 (SD 32) Mean 122ms.

**Correlation between closure duration and voicing amplitude**
A positive correlation between closure duration of an implosive and voicing amplitude was indicative in our data. Figure 6 shows the closure duration and voicing amplitude for [ɗ] in an intervocalic, analogous environment. This point will be examined further.

Figure 6. Correlation between the closure duration and voicing amplitude for [ɗ] in intervocalic analogous environment. Pooled for four speakers.

**Variability**
Speaker differences and token-to-token variability have been reported to play a very important role in the realization of the implosive in Xhosa (Jessen 2002). Even in the present data, clear cross-speaker variability in the production of plosives and implosives exists. However, variability due to position in utterance as well as token-to-token variability were negligible in our data.

**Conclusion**
The acoustic phonetic properties in Mpiemo implosives and voiced plosives showed more similarities to Edoid and Ijo languages spoken in Nigeria (Lindau 1984) than to other Bantu language like Xhosa spoken in South Africa (Jessen 2002). More detailed quantitative analysis is in progress.

**References**