Voiceless implosives in Seereer-Siin

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This paper provides articulatory and acoustic data on voiceless implosive stops in Seereer-Siin, an Atlantic language of the Niger-Congo family spoken in Senegal. Seereer is characterized by pairs of voiced and voiceless implosive stops in three places of articulation. These pairs are phonemically contrastive in lexical items. Oral air pressure measurements from Seereer stops uphold Clements & Osu's (2002) proposal that implosives and other non-explosive stops are characterized by the absence of positive oral air pressure rather than the presence of negative oral air pressure during occlusion. Acoustic data show that voiceless implosives are characterized by a short period of silence ranging from approximately twenty to fifty milliseconds before the onset of prevoicing prior to release. These findings replicate to a certain extent those of Faye & Dijkstra (1997).

1 Introduction

Sounds commonly referred to in the literature as implosives are found in approximately ten percent of the world's languages (Ladefoged & Maddieson 1996: 82), a high concentration of which are to be found in West Africa (Maddieson 1984). Recent renewed interest in the phonetic status of implosive stops, traditionally understood to mean stops characterized by glottalic ingressive airflow, has begun to change our understanding of these problematic consonants. The goal of this article is to document two phonetic characteristics, namely oral air pressure and voicing during occlusion, of implosive consonants in Seereer-Siin, a Northern Atlantic language of the Niger-Congo phylum spoken in Senegal, in light of recent hypotheses concerning the nature and patterning of such sounds (Goyvaerts 1988; Stewart 1989; Kutsch Lojenga 1991, 1994; Creissels 1994; Demolin 1995; Ladefoged & Maddieson 1996; Clements 2000; Clements & Osu 2002).

Seereer-Siin is of substantial phonetic interest in that it has a phonologically contrastive set of voiced and voiceless implosive stops in three places of articulation. While the former are commonly found among languages that have implosive stops, the latter are much less frequently attested. With regard to the laryngeal setting of implosive stops, Ladefoged (1982: 122) writes, 'In the production of implosives, the downward moving larynx is not usually completely closed. The air in the lungs is still being pushed out, and some of it passes between the vocal cords, keeping them in motion so that the sound is voiced'. While this description suggests that voicing is the unmarked laryngeal setting for implosive stops, a view that is supported by the relative infrequency with which voiceless implosives are reported to occur in the world's languages, like Catford (1977), it does not rule out the possibility that the larynx may be completely closed, resulting in the production of a voiceless implosive stop. Thus,

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Ladefoged & Maddieson (1996: 87) state that 'implosives can vary between modal voicing and a more constricted phonatory setting'.

While the vast majority of implosives in the world's languages are voiced, there are nonetheless several empirical studies that document the existence of voiceless implosives. For example, Owerri Igbo (Ladefoged et al. 1976) and the Uzere dialect of Isoko (Donwa 1982) both have a voiceless bilabial implosive, and Lendu (Kutsch Lojenga 1991, Demolin 1995) and Ngiti (Kutsch Lojenga 1994), two Nilo-Saharan languages spoken in the eastern part of the Democratic Republic of Congo (formerly Zaïre), appear to have the same set of voiceless implosives as Seereer-Siin (Demolin 1995, Goyvaerts 1988). Faye & Dijkstra (1997) provide an earlier phonetic study of implosive stops in Seereer-Siin in comparative perspective, concluding that they are phonemically contrastive in Seereer but not in Noon or Safi-Safi, the two other Atlantic languages in their study.

Clements & Osu (2002) propose that implosive stops form part of a class of sounds captured by the term non-explosive stops whose underlying phonological commonality is non-obstruence. Such sounds, as Clements & Osu define them, are characterized by an absence of positive oral air pressure during occlusion, rather than by negative oral air pressure or rarefaction. Earlier phonetic studies that support their hypothesis include Ladefoged et al. (1976: 154), who comment on Owerri Igbo as follows: 'it seems that [b'] contrasts with [b] simply by having no increase (rather than by having an actual decrease) in oral pressure during the closure'. As the discussion in section 3.1 below shows, articulatory data from Seereer-Siin bear out the hypothesis that implosives need not involve negative air pressure.

1.1 Seereer-Siin

Seereer is a member of the northern branch of the Atlantic family of Niger-Congo languages and is spoken by approximately one million native speakers (Grimes 2000) in the west central area of Senegal and parts of coastal Gambia in the West African sahel. It is most closely related to Fula and shares many phonetic, phonological, morphological and other grammatical characteristics with that language. There are four main dialects of Seereer. Seereer-Siin, the subject of this study, also referred to in the literature as Singandum or Kéguem (W. C. Faye 1979, S. Faye 1999) is spoken in the inland area of Senegal that corresponds to the precolonial kingdom of Sine (Siin) and surrounding areas, including the city of Kaolack and the towns of Fatick and Diakhao. The dialect of the Petite Côte, sometimes called Jegem or Ndyegem (Senghor 1944, Sapir 1971), is spoken on the Atlantic littoral between Mbour and Joal. Sapir (1971) considers this coastal dialect a variant of Seereer-Siin, although both Crétois (1972) and Fal (1980) attest to significant phonological and, to a lesser extent, morphological distinctions between the two. A third dialect is spoken by the 'Water Seereer' or Nyominka who live on the islands in and around the mouth of the Saloum river, including Dionewar and Niodior, and further south to the Gambia and to the Casamance region of southern Senegal. Finally, the small shell-covered island of Fadiouth, connected by bridge to the mainland at Joal, gives its name to a fourth Seereer dialect spoken on the island itself and in a few areas to the south. The Siin dialect is the only one of the four to have contrastive voiced and voiceless implosive stops; other dialects have only voiced implosive stops.[1]

[1] Seereer-Siin's sister language, Fula, also has voiced implosives in three places of articulation, bilabial, alveolar and palatal, but no distinctive voiceless implosives. The Arabic voiceless uvular stop, [q], has been borrowed into the Pulaar dialect of Fula, spoken in the Fouta Toro region of northern Senegal, as a voiced uvular implosive stop, as in the word ʛurʔaan 'Qur'an'. This sound does not otherwise form part of the Pulaar phonemic inventory.

2 Contrastiveness between voiced and voiceless implosives

The consonantal inventory of Seereer-Siin, given in (1), is typical of a Niger-Congo language (Clements 2000: 125), with two exceptions. The first of these is the presence of the two uvular sounds, a voiceless uvular stop [q] and a prenasalized voiced uvular stop [ᴺɢ]. There is, however, no voiced uvular plain stop [ɢ]. The second exception is the presence of voiceless implosive stops in three places of articulation.

(1) *The consonantal inventory of Seereer-Siin*

	Labial	Coronal	Palatal	Velar	Uvular	Glottal
Plosive	p	t	c	k	q	ʔ
	b	d	ɟ	g		
Implosive	ɓ̥	ɗ̥	ʄ̥			
	ɓ	ɗ	ʄ			
Prenasalized	ᵐb	ⁿd	ᶮɟ	ᵑg	ᴺɢ	
Fricative	f	s		x		h
Nasal	m	n	ɲ	ŋ		
Flap		r				
Lateral		l				
Glide	w		j			

Greenberg's (1970) hypothesis that there are no phonemic contrasts within the class of glottalic consonants, which includes implosives and ejectives, has been called into question by data from African languages such as Owerri Igbo (Ladefoged et al. 1976), Lendu (Goyvaerts 1988, Kutsch Lojenga 1991, Demolin 1995) and Ngiti (Kutsch Lojenga 1994) that, like Seereer-Siin, contrast voiced implosives with the less common voiceless implosives. Cross-linguistically, however, voicing appears to be the only type of phonologically significant phonation type contrast within the class of implosive consonants (Clements & Osu 2002: 300). The bilabial, alveolar and palatal voiceless implosives, transcribed here as [ɓ̥], [ɗ̥] and [ʄ̥], respectively, occur primarily, but by no means uniquely, within the context of stem-initial consonant mutation, where they alternate systematically and meaningfully with their voiced counterparts [ɓ], [ɗ] and [ʄ]. Patterns of stem behavior in Seereer-Siin provide evidence that initial implosive consonants in nominal stems are underlyingly voiceless, while in verb stems they are underlyingly voiced (Mc Laughlin 1994, 2000). Their phonemic status is further supported by minimal pairs such as those in (2) which illustrate the high functional load carried by the distinctiveness between voiced and voiceless implosives within the context of consonant mutation, namely number in verbs. In verbs whose stem begins with a non-mutating consonant, number is indicated alternatively by the suffix /-jo/ (Fal 1980: 99ff.). Consonant mutation and the suffixation of /-jo/ do not co-occur.

(2)
a ɓira 'he/she milks' (e.g. a cow)
a ɓ̥ira 'they milk'
a ɗega 'he/she cuts'
a ɗ̥ega 'they cut'
a ʄaxa 'he/she crunches'
a ʄ̥axa 'they crunch'

Other mutating consonant pairs that show a contrast between voiced and voiceless forms include [p] and [b], [t] and [d], and [k] and [g]. These also alternate with voiced prenasalized stops, which the implosives, being incompatible with nasality, do not.[2]

While consonant mutation is a likely candidate for the environment in which voiceless implosives emerged historically, voiced and voiceless implosives are also contrastive outside the context of consonant mutation, as the following minimal pairs (from Fal 1980 and S. Faye 1999) illustrate:

(3)

bilabial			
ɓaj	‘hand/arm	ɓ̥aj	‘breeze’
ɓood	‘to crawl	ɓ̥ood	‘serpent’
alveolar			
biɗ	‘flower	biɗ̥	‘sifting’
faɗ	‘to slap’	faɗ̥	‘to stop up a hole’
palatal			
ʄaar	‘to have ringworm’	ʄ̊aar	‘residue after grinding grain’
xeʄ	‘to be quenched’	xeʄ̥	‘to be contained’

These minimal pairs, many from unrelated stems – hence outside the domain of consonant mutation, should leave no doubt as to the contrastiveness and phonemic status of voiced and voiceless implosives in Seereer-Siin.

3 The phonetics of implosives

Previous instrumental phonetic studies of implosives in Seereer-Siin include Ladefoged (1964), Fal (1980) and Faye & Dijkstra (1997).[3] Ladefoged (1964: 17) comments on the very brief period of glottalization in the production of voiced implosive sounds, leaving open the question of whether they are in fact implosive stops, or simply plain stops accompanied by a glottal stop. In Fal's description the voiceless implosive stops are aspirated but realized as voiced [*aspirés*, *réalisés sonores*], but she admits that this is a tentative hypothesis subject to confirmation by further research. Faye & Dijkstra's phonetic study compares the implosives in Seereer-Siin to those in Saafi-Saafi and Noon, two Cangin (Northern Atlantic) languages also spoken in Senegal. Their conclusions are that voiceless implosives occur in all three languages, but they are phonemically distinct only in Seereer-Siin. In Saafi-Saafi and Noon they occur in free variation with voiced implosives in what Faye & Dijkstra describe as word-initial position, but which may be post-pausal position.

Two separate experiments were carried out for this study. The first measured oral air pressure during occlusion in the production of voiced and voiceless implosives in intervocalic position in meaningful phrases. The second experiment, which was conducted separately, involved the recording of acoustic data in the production of the same tokens. The subject was a 32-year-old male from the village of Nguéniène in Senegal, a native speaker of Seereer-Siin who also speaks Wolof, French and English.

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[2] There is a second type of consonant mutation in Seereer-Siin (Fal 1980, Mc Laughlin 1994, 2000) which more closely resembles the Fula pattern and in which consonants alternate between a continuant, a stop, and a presnasalized stop. Implosive consonants do not participate in that type of mutation.

[3] Demolin et al. (2002) also mention discussion of the phonetics of these sounds in Waly Coly Faye's 1979 thesis which was, unfortunately, not available for this study.

3.1 Oral air pressure

The articulatory correlate of voiceless implosives in Seereer-Siin examined in this study was intraoral air pressure. Oral air pressure was examined under the hypothesis that implosive stops are characterized by rarefaction, namely a measurable drop in pressure, as the glottis lowers after closure.

3.1.1 Procedure

An Intramedic Luer stub adaptor and a Honeywell Microswitch pressure transducer were coupled to a piece of 1.77 mm Intramedic polyethylene tubing measuring 80 mm in length. The tube was inserted orally to sample air pressure. The air pressure signal was conditioned and filtered by a bridge amplifier, and a 10 cm H_2O pressure source in the form of a U-tube manometer was used to calibrate the air pressure transducer.[4] Measurements were taken of two tokens each of three sets of voiced implosives and three sets of voiceless implosives. All tokens occurred in intervocalic position in meaningful words or phrases whose translations are provided in the appendix. The results are given in tables 1–3. As a control, measurements were also taken of two tokens each of two sets of voiced and voiceless plosive stops in meaningful utterances. Translations for the utterances are given in the appendix.

3.1.2 Results and discussion

The resulting measurements for the implosive stops are given in tables 1–3.

Table 1 Oral air pressure (cm H_2O) per token or bilabial implosive stops.

Voiced bilabial [ɓ]

1. a ɓira	−0.5	−1.5
2. kaa ɓaal	−6.0	−6.0
3. a ɓoɗ̥a	−6.0	−6.0

Voiceless bilabial [ɓ̥]

4. a ɓ̥ira	−5.5	−5.0
5. gaada ɓ̥aal	−2.0	−2.2
6. gaada ɓ̥oɗ̥	−0.3	−1.5

Table 2 Oral air pressure (cm H_2O) per token for alveolar implosive stops.

Voiced alveolar [ɗ]

1. a ɗaxa	0	−0.1
2. a ɗega	−2.0	−2.0
3. a ɗiisa	−2.0	−2.0

Voiceless alveolar [ɗ̥]

4. gaada ɗ̥ax	−6.0	−6.0
5. a ɗ̥ega	−5.0	−6.0
6. a ɗ̥iisa	−1.0	−0.5

Table 3 Oral air pressure (cm H_2O) per token for palatal implosive stops.

Voiced palatal [ʄ]

1. kaa ʄaar	−2.0	−2.0
2. a ʄaxa	−2.0	−3.0
3. a ʄooka	−0.5	−3.0

Voiceless palatal [ʄ̥]

4. gaada ʄ̥aar	0	−4.0
5. a ʄ̥axa	−1.5	0
6. a ʄ̥ooka	−1.75	−3.0

[4] The program and the air pressure equipment on which the measurements were taken were developed by Steven Barlow of the University of Kansas who assisted me in carrying out the experiment. More detail on the equipment can be found in Barlow, Suing & Andreatta (1999).

As a control, measurements were also taken of two tokens each of two sets of voiced and voiceless plosive stops in meaningful utterances. Translations for the utterances are given in the appendix. Results are given in tables 4–6.

Table 4 Oral air pressure (cm H_2O) per token for bilabial plosives.

Voiced bilabial [b]			Voiceless bilabial [p]		
1. biiɲ	5.0	8.0	3. poɡ	10.0	14.0
2. buf̥	10.0	13.0	4. ɟapil	9.75	9.5

Table 5 Oral air pressure (cm H_2O) per token for alveolar plosives.

Voiced alveolar [d]			Voiceless alveolar [t]		
1. odon	4.0	3.0	3. xaton	1.5	1.5
2. dox	0.5	0.5	4. otew	0.5	0.5

Table 6 Oral air pressure (cm H_2O) per token for palatal plosives.

Voiced palatal [ɟ]			Voiceless palatal [c]		
1. oɟan	3.5	1.0	3. cer	4.0	7.0
2. ɟapil	1.5	0.75	4. acaf	14.0	11.0

What these measurements show is that plosive stops invariably exhibit positive oral air pressure, but implosive stops exhibit either negative oral air pressure or a neutral ambient air pressure that registers neither negative nor positive. In no cases did the implosives register positive oral air pressure.

While tables 4–6 show positive oral air pressure for all plosive stops, ranging from 0.5 cm to 14.0 cm H_2O, the findings reported in Tables 1–3 reveal negative readings for oral air pressure within a range of –0.5 cm H_2O to –6.0 cm H_2O for 33 out of 36 implosive tokens. The three remaining tokens had a reading of 0 cm H_2O, indicating neither negative nor positive air pressure in the production of the implosives. Both voiced and voiceless implosives registered negative oral air pressure following glottal closure and voicing could not be correlated with a greater or lesser decrease in oral air pressure. For two of the three pairs of implosive bilabial stops the voiced ones (table 1: 2 and 3) registered a greater decrease in oral air pressure than the voiceless ones (table 1: 5 and 6); the opposite was true for the third (table 1: 1). Alveolar stops had a similar pattern: in two cases (table 2: 4 and 5) the voiceless tokens had a much greater drop, down to –5 cm and –6 cm H_2O, but in the third case (table 2: 6) the voiceless tokens showed negligible negative air pressure, –1.0 cm and –0.5 cm H_2O, not that far removed from the dip of –2.0 cm H_2O for the voiced counterpart (table 2: 3). The palatal implosive stops (table 3) show more or less parity between voiced and voiceless forms with regard to negative air pressure, but registered a lesser overall decrease in oral air pressure than bilabials or alveolars. Two voiceless palatal tokens (table 3: 4 (token 1) and 5 (token 2)) and a single voiced alveolar token (table 2: 1 (token 1)) registered neither positive nor negative oral air pressure, with a measurement of 0 cm H_2O.

3.1.3 Conclusion

The results of this experiment, which includes tokens whose oral air pressure measured 0 cm H_2O, do not support the hypothesis that implosive stops are characterized by negative oral air pressure. Rather than suggesting that those tokens do not represent implosive stops, the

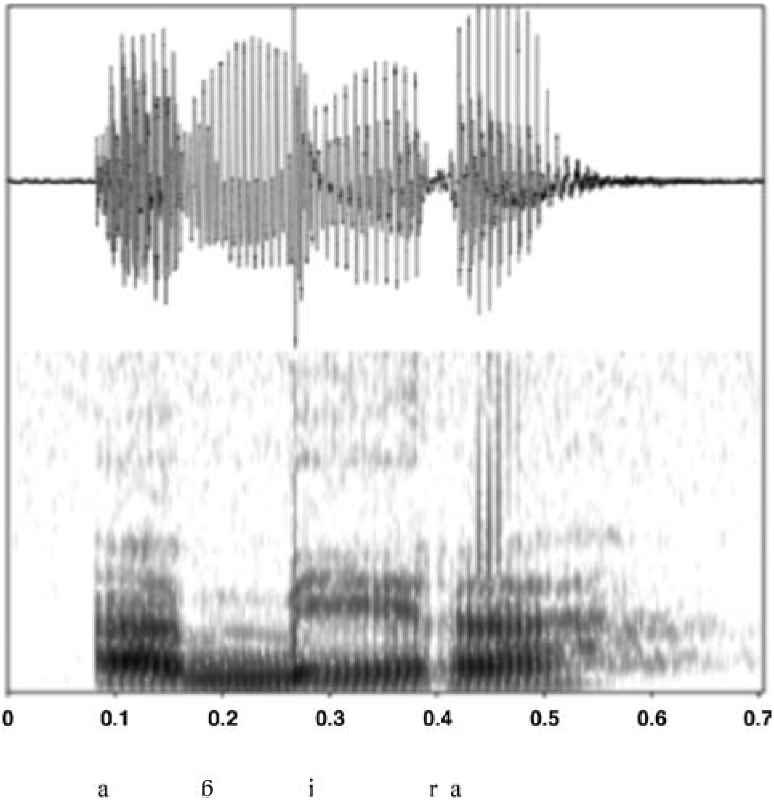

Figure 1 Waveform and spectrogram of the utterance [a ɓira].

findings are consistent with Clements & Osu's (2002) characterization of implosives and other non-explosive stops. Consonant with earlier observations that implosives do not always show rarefaction (Ladefoged 1971: 26; Ladefoged et al. 1976: 154), they propose that instead of negative oral air pressure, 'the feature which underlies implosives and other non-explosive stops is *non-obstruence*, defined as the absence of positive oral air pressure during occlusion' (2002: 301). This characterization covers all cases in the implosive data measured in this study, thus the facts of Seereer-Siin support Clements & Osu's claim about the characteristics of such sounds.

3.2 Voicing

Turning now to the acoustic data, the same phrases containing implosives that were measured for oral air pressure were recorded separately on a Marantz analog tape recorder, converted to digital form, and analyzed by spectrogram on Praat speech analysis software. The acoustic profile of voiceless implosives emerging from these analyses is similar to the characterization of voiceless implosives in other languages such as Lendu (Demolin 1995), Ngiti (Kutsch Lojenga 1994) and Igbo (Ladefoged et al. 1976), where a period of silence is followed by a period of prevoicing before release.

Findings show that in intervocalic position the voiceless implosives are characterized by a period of silence that lasts anywhere from approximately 20 to 50 milliseconds with a mean in the mid thirties. A similar period of silence is not evidenced in the voiced implosives, as shown by the spectrograms in figures 1–6 that contrast voiced and voiceless implosives in

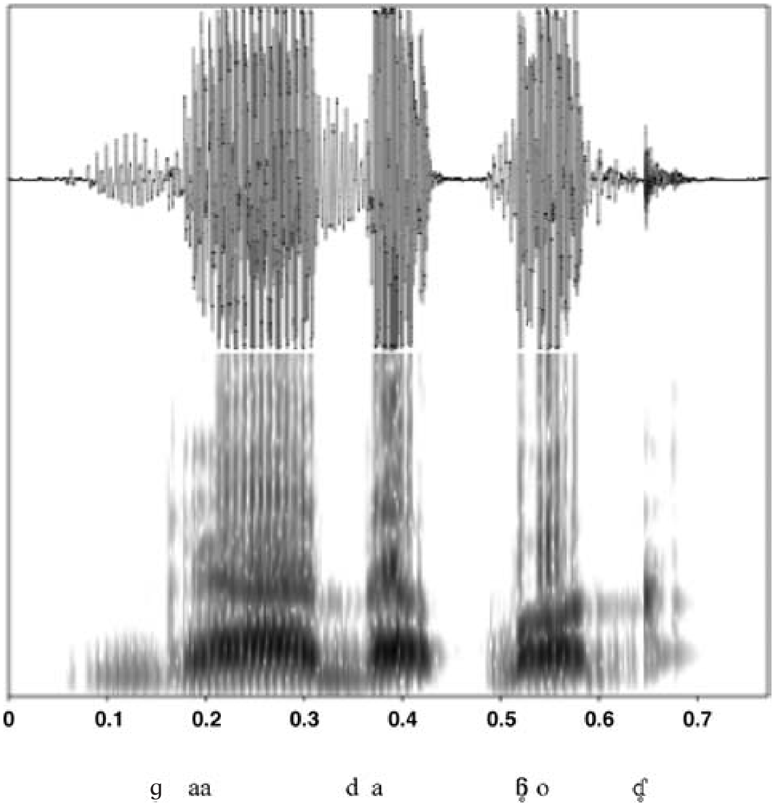

Figure 2 Waveform and spectrogram of the utterance [gaada ɓ̥oɗ̥].

the three places of articulation. This distinction suggests that the implosives in question are indeed voiceless, and reproduce to a certain extent the findings of Faye & Dijkstra (1997) in their comparative study of glottalized consonants in Seereer-Siin, Saafi-Saafi and Noon. For Seereer-Siin they found a period of approximately 60 milliseconds of silence, so slightly longer than, but close to, the measurements reported here.

A period of prevoicing is also evidenced in the spectrograms under consideration, and is consistently longer than the period of silence that precedes it. It ranges from approximately fifty to one hundred and ten milliseconds, the upper end being characteristic of the voiceless palatal implosives. Kutsch Lojenga (1991) and Demolin (1995), in separate studies of implosive consonants in Lendu, an unrelated language which appears to have the same series of voiced and voiceless implosives as Seereer-Siin, both find a period of prevoicing immediately before or right at the release of closure of the voiceless segments. Kutsch Lojenga (1991: 83) says that 'a minimal degree of voicing appears to be an articulatory necessity.' Demolin (1995: 375) adds that 'This prevoicing corresponds to an opening of the vocal folds before the oral closure release and before the larynx executes its upward movement'. He suggests a profile of voiceless implosive stops (Demolin 1995: 372) in which 'after the initial closure of the stop, the glottis remains closed for a period of time before the larynx is lowered. During this downward movement of the larynx, the glottis remains closed most of the time and therefore no voicing results ... Before the larynx starts rising to recover its initial position, voicing of considerable amplitude appears up to the release of oral closure'.

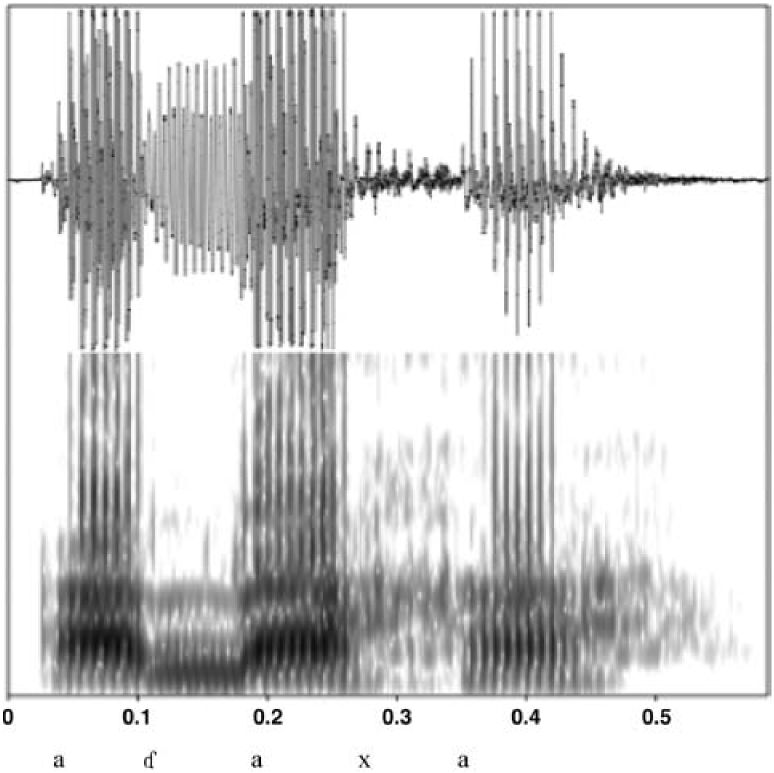

Figure 3 Waveform and spectrogram of the utterance [a ɗ̥axa].

Only synchronized acoustic and articulatory data will be able to confirm that Seereer-Siin voiceless implosives follow similar patterns of prevoicing to those found in other languages.[5]

4 Conclusion

In this brief article I have presented articulatory and acoustic data that provide strong evidence of the existence of voiceless implosive segments in Seereer-Siin. Based on the articulatory data, which show a lack of positive ambient oral air pressure, I concur with Clements & Osu (2002) that such segments are better characterized by an absence of positive oral air pressure rather than rarefaction.

[5] As an anonymous *JIPA* reviewer points out, the period of prevoicing in the production of voiceless implosives goes against Stevens & Blumstein's (1981) attempt to define an invariant acoustic correlate for voicelessness. If, however, their definition of voicelessness based on low frequency spectral energy (1981: 30) is limited to obstruents, then these findings would further support Clements & Osu's (2002) position that implosives are non-obstruents.

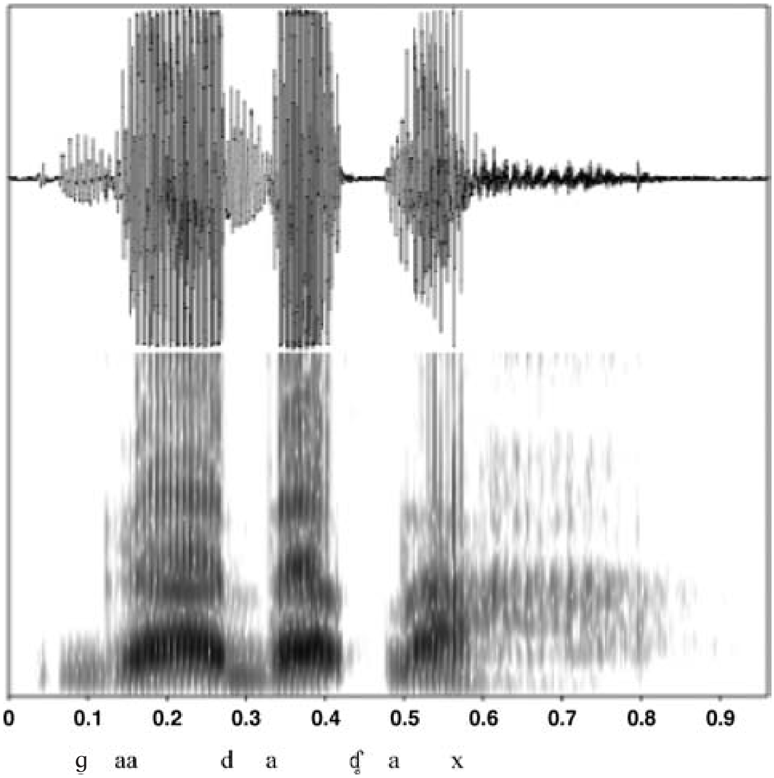

Figure 4 Waveform and spectrogram of the utterance [gaada ɗ̥ax].

4.1 Limitations of the study

This paper provides a preliminary profile of two of the phonetic properties of voiceless implosives in Seereer-Siin, but it also raises many questions that will have to be answered by future research on the language. Notably, the study is limited by the fact that the articulatory and acoustic data were not gathered or recorded simultaneously, but rather sequentially from two different sets of tokens. Moreover, the sample involved only a single subject, an obvious shortcoming for the collection of representative data. Finally, no visual record of the utterances was made that would allow us to correlate visual cues with articulatory ones.

A visual record of the utterances would allow some clarification of how the voiced and voiceless implosives differ with regard to the timing of laryngeal lowering. If the timing of the lowering gesture is the same for both, then the difference between them must be attributable to some other factor such as the state of glottal aperture or laryngeal tension early on in the lowering gesture. In the production of a voiceless implosive, a shift would occur at the onset of prevoicing so that it would then exhibit the same values for glottal aperture or laryngeal tension as the voiced implosive. Conversely, if the laryngeal state is the same for both, then we would expect the timing of the lowering gesture to be later for the voiceless implosive.[6] A visual record would help to resolve this issue in particular.

[6] I am grateful to John Esling for drawing my attention to this crucial point.

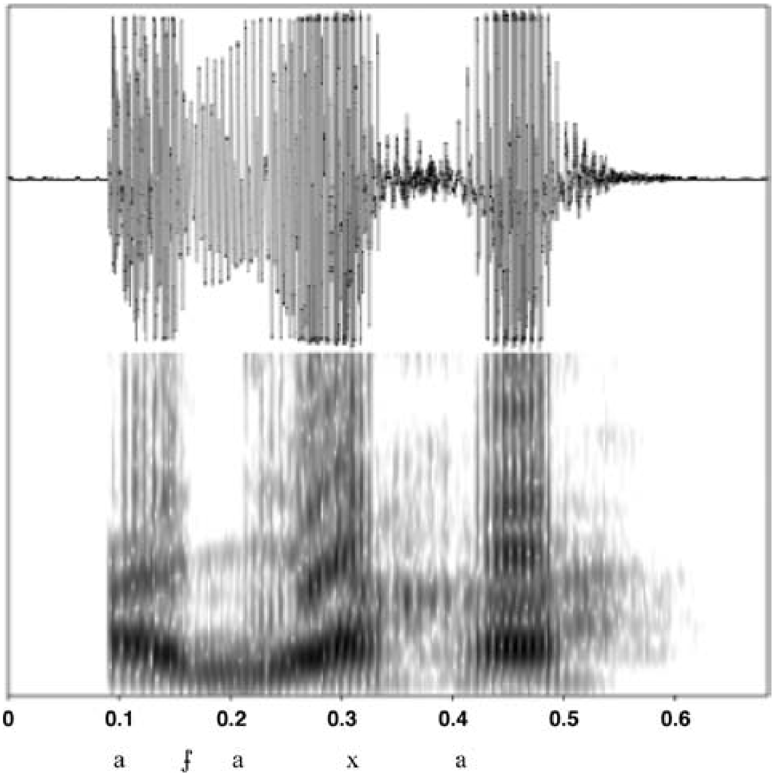

Figure 5 Waveform and spectrogram of the utterance [a ʄaxa].

4.2 The patterning of non-obstruents

Clements & Osu (2002) consider the phonological correlate of the absence of positive oral air pressure to be non-obstruence, and show how non-explosive stops, including implosives, frequently pattern with sonorants, especially nasals and laterals. In Seereer-Siin and Pulaar, for example, implosives cannot be prenasalized.[7] This patterning with sonorants would in part explain the unmarked value of [+voice] for implosives as opposed to the [–voice] value for other stops pointed out by Creissels (1994). Conversely, non-explosive stops tend to pattern with obstruents with regard to most of their sonority-related distributional properties, such as favoring syllable onsets as in Seereer. This additional observation leads Clements & Osu (2002: 337) to espouse a proposal made by Stewart (1989) that non-explosives can be viewed phonologically as consisting of the features [–obstruent] and [–sonorant].

4.3 Voiceless implosives and the IPA

This article has also provided an additional incentive for the reintroduction of the independent hooktop symbols for voiceless implosives into the International Phonetic Alphabet, rather than

[7] Other examples include the facts that both non-explosive stops and sonorants are disfavored in nasal-stop clusters, and non-explosive stops are widely excluded from the class of depressor consonants (Clements & Osu 2002: 335). To these can be added the fact that an unexploded palatal implosive in Hendo (Bantu) is an allophone of the vowel /i/ (Demolin et al. 2002).

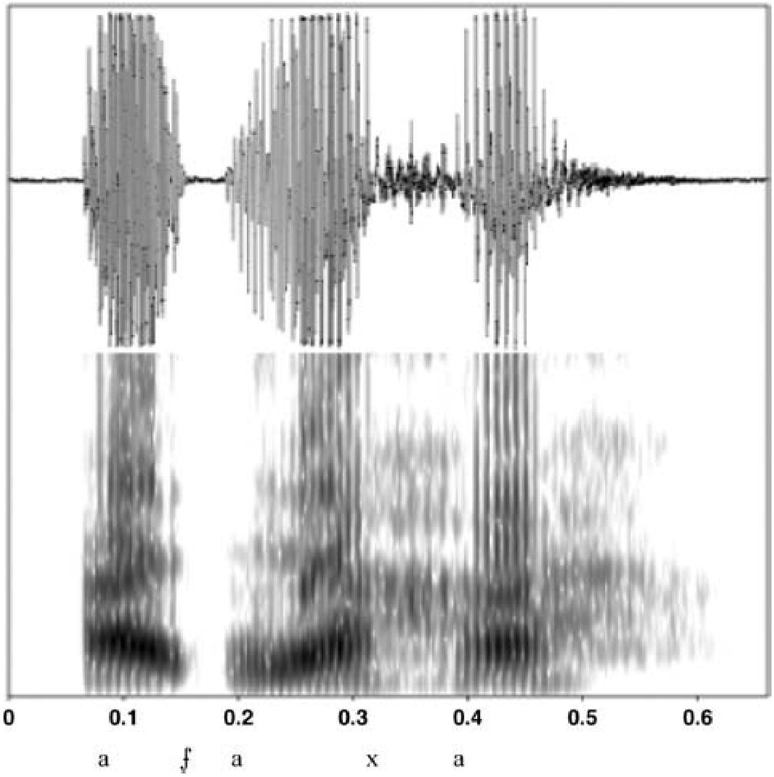

Figure 6 Waveform and spectrogram of the utterance [a ʄ̥ax].

simply adding the voiceless diacritic to the symbols for voiced implosives. The distribution of voiceless implosives in Seereer, including within the morphologically conditioned context of consonant mutation, shows that they are contrastive and have phonemic status in the language. Although they are used in standard Seereer-Siin orthography and represent sounds that have phonemic status in the language, these symbols were shortlived within the IPA, finding their way into the 1989 version (International Phonetic Association 1989) only to meet with a proposal for their removal a year later (Pullum 1990; International Phonetic Association 1990) and were, in fact, removed in the 1993 revision (International Phonetic Association 1993). The contrastiveness of voiced and voiceless implosive stops in Seereer-Siin should be a point in favor of the reintegration of the symbols into the IPA as counterparts to the voiced forms, since it is one of the primary criteria for inclusion.

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Appendix

The following meaningful phrases containing implosives were used in the oral air pressure and acoustic experiments described in this study.

a ɓira	'He/she milks (e.g. a cow)'
a ɓ̥ira	'They milk'
kaa ɓaal	'He/she has lice'
gaada ɓ̥aal	'They have lice'
a ɓoɗ̥a	'He/she strangled'
gaada ɓ̥oɗ̥	'They strangled'
a ɗaxa	'He/she treated (e.g. a wound)
gaada ɗ̥ax	'They treated'
a ɗega	'He/she cut'
a ɗ̥ega	'They cut'
a ɗiisa	'He/she sews'
a ɗ̥iisa	'They sew'
kaa ʄaar	'He/she has ringworm'
gaada ʄ̥aar	'They have ringworm'
a ʄaxa	'He/she crunched'
a ʄ̥axa	'They crunched'
a ʄooka	'He/she noticed'
a ʄ̥ooka	'They noticed'

The following words containing plosives were used as a control for oral air pressure measurements.

biiɲ	'wine'
buʄ̥	'fly'
pog	'traps'
ɟapil	'knife
odon	'mouth'
dox	'burn'
xaton	'mouths'
otew	'woman'
oɟan	'horn'
cer	'body'
acaf	'leg'