



Received 18 May, 2020; revised 21 July, 2021; accepted 13 October, 2021. © 2022 Martine Bruil & Jesse Stewart.  
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# Phonetics and phonology of nasality in Ecuadorian Siona

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This study describes the nasal system in Ecuadorian Siona, an endangered Western Tukanoan language spoken in the Ecuadorian province of Sucumbíos, using the Earbuds Method to analyze nasal events acoustically. This method provides a visual representation of the timing and duration of velum gestures through intensity (dB) and amplitude (Pa) fluctuations in the nasal and oral cavities. The studied events include nasal spreading (nasal harmony), triggers, targets, blockers, and transparent segments. Meanwhile, differences between nasal phonemes and nasal allophones are also identified along with the effects of morpheme boundaries during nasal spreading events. Results reveal that, unlike many other Tukanoan languages, /m/ and /n/ function as individual phonemes independent of their oral counterparts (/p/ & /t/). In addition, nasal harmony was identified as predominantly rightward spreading apart from syllable-delimited leftward spreading to vocoid segments. Moreover, suffixes responsible for blocking nasal spreading appear to be reminiscent of oral suffixes in Eastern Tukanoan languages. Finally, more blockers were identified in Ecuadorian Siona than in most Eastern Tukanoan languages.

*Keywords:* nasality; Earbuds Method; Siona; Tukanoan

## 1 Introduction

Ecuadorian Siona (henceforth Siona), an endangered Western Tukanoan<sup>1</sup> language spoken in the eastern lowlands of Ecuador (Figure 1), possesses a number of understudied nasal phenomena in its phonology, which differ from other languages in its family. Past descriptions of such phenomena have been mainly impressionistic in nature, using the intuition of native speakers and linguists alike. However, if such descriptions are accurate, they have far reaching consequences for our synchronic and diachronic understanding of nasality in Tukanoan languages. This study makes use of empirical data analyzed

\* We would like to graciously thank the Siona speakers, Agustín Yiyoguaje†, Alicia Suale, Darwin Yiyoguaje, Elena Yiyoguaje, Ernestina Piaguaje, Herberina Piaguaje, Irma Yiyocuro, Jairo Payaguaje, Janeth Piaguaje, Luis Payaguaje, Magdalena Piaguaje, Teofilo Payaguaje, and Yolanda Piaguaje, for their time, enthusiasm, and dedication to this project. We are also very grateful to the Sototsiaya community for their warm hospitality. Our gratitude goes also out to Ligia Criollo for her teachings on Ecuadorian Siona nasality. We are also indebted to Gabriela Prado and Eduardo Portilla for their field assistance. We also thank Marijn van ‘t Veer and Rik van Gijn for their comments on previous versions of this paper. Additionally, we would like to express our gratitude to the editor and the anonymous reviewers for their invaluable comments that helped improve this paper. All remaining errors are ours.

This research was funded by the University of Saskatchewan (Fund #416894) and the LABEX ASLAN (ANR-10-LABX-0081) of Université de Lyon within the French program “Investissements d’Avenir” (ANR-11-IDEX-0007).

† We use the standard orthographic conventions for language names influenced by the recent Tukanoan literature.

acoustically using a novel method that allows for the collection of primary nasal data in the field. Through this analysis, we aim to strengthen our understanding of Tukanoan nasality.

Like other Tukanoan languages, Siona exhibits nasal harmony, yet there appear to be several differences regarding how nasal and oral segments affect the triggering and blocking of nasal spreading events. Additionally, unlike other Tukanoan languages, both Ecuadorian and Colombian Siona have been described as having nasal phonemes (Bruil 2014; Wheeler 1987). As a result, reconstructions of Proto-Tukanoan have included /m/ and /n/ in its phonological inventory (Chacon 2014; Waltz & Wheeler 1972). As the presence of such phonemes appears to be a unique case in the Tukanoan family, this paper sets out to describe the nasal system in Siona using the Earbuds Method (Stewart & Kohlberger 2017) to analyze nasality in elicited speech recorded in the field.



Figure 1: Locations of the Ecuadorian Siona communities Sototsiaya and Puerto Bolívar

In this paper, we describe Siona's inventory of phonemic oral and nasal segments and how they function as nasalizers, blockers, targets, and transparent segments. We address the directionality of nasal spreading and we argue that nasality in Siona targets individual segments in rightward spreading events whereas leftward spreading events affect the domain of the syllable. Finally, we look at the role compounding and grammaticalization play in blocking nasal spread in the language. This paper makes use of acoustic measurements taken from the field to support our phonological analysis of nasality phenomena in Siona. In §2, we discuss background information on nasality (§2.1) and the Earbuds Method (§2.2). We continue with a general overview of Siona phonology (§3). We then lay out our method for data collection and analysis in §4 and provide our results in §5. In §6, we provide an overview of nasality in Tukanoan languages in order to understand Siona nasality from a broader perspective. We conclude with a discussion of our results and provide a comparison with other Tukanoan languages in §7.

## 2 Measuring nasality

To analyze the nasal properties of Ecuadorian Siona phonology, we begin by introducing the concept of nasality by means of a typological overview (§2.1). This is followed by an explanation of a novel method used to collect and analyze nasal data from the field (§2.2).

### 2.1 Nasality

Nasal segments are found in the vast majority of the world's languages, with just 13 out of the 567 languages sampled described as having no nasal segments in their sound inventories (Maddieson 2013). These languages typically fall within two agreed upon classifications (i) languages found in the Pacific Northwest of the United States, (e.g., Quileute) where the lack of nasals is an areal feature and (ii) languages with nasal harmony in which nasality is treated as a morpheme-level feature. Some Eastern Tukanoan languages fall into the latter type, which are further discussed in §6 (e.g., Barasana (see e.g., Gómez-Imbert 2003, 2004), Desano (see e.g., Kaye 1971; Silva 2012), Kotiria (see e.g., Stenzel 2007, 2013), and Tatuyo (see e.g., Gómez-Imbert 2004)).

Nasality is the result of an articulatory process involving the separation of the velum from the posterior pharyngeal walls during the production of speech sounds. This configuration creates coupling of the oral and nasal tracts, which forces air into the nasal cavity and the nose. The amount of air forced through the nose can differ greatly, ranging from clearly audible nasal sounds to imperceptible nasal leakage. An example of the latter is described in Silverman (2017) where low vowels in English, in particular /ɑ/, are often produced with velic lowering in oral contexts. Similarly, some degree of velum-pharyngeal separation also takes place during the production of voiced stops with pre-voicing (negative VOT) to maintain adequate levels of pressure for vocal fold vibration during the oral closure phase; Wetzel and Nevins (2018: 6) describe this as “nasal venting.”

Nasality can target individual segments, segment clusters, or even entire words, yet the gesture is not necessarily aligned with a specific unit and as pointed out in Cohn (1990) the timing of nasal gestures is asymmetric cross-linguistically. For example, velic gestures may be anticipated causing pre-target segments to undergo some degree of nasalization (known as pre-nasalization, leftward spread, anticipatory, or regressive nasalization). In other cases, the raising of the velum may not take place until some point in post-target segments (known as post-nasalization, carryover, rightward spread, or progressive nasalization). If nasality is treated as ‘suprasegmental’ (i.e., having the potential for long-distance transmission over a series of segments that serves a phonological and/or morphological purpose), then the language in question may in fact lack nasal phonemes all together, as is the case with the previously mentioned Eastern Tukanoan languages (Barasana, Desano, Kotiria, & Tatuyo).

One of the most clear-cut cases of nasality functioning as a suprasegmental process involves nasal spreading (or nasal harmony). From a phonological perspective, nasal harmony involves passing along the nasal feature from a ‘trigger’ segment to neighboring segments or across an entire word in a given direction (e.g., to the left or right of the trigger). In this case, the segments within the path of nasal harmony could be said to undergo assimilation to the nasal feature ([+NASAL]).<sup>2</sup> From a phonetic perspective, nasal harmony can be described as either the lowering of the velum in anticipation of a nasal event (leftward spreading), the continued aperture after a nasal event (rightward spreading), or bidirectional spreading, as in Applecross Gaelic (see e.g., Walker 2000).

Nasal harmony is a typologically common phenomenon, yet languages differ as to its application with respect to three primary factors (see Cohn 1993 for a critical overview). The first involves the direction of the nasal spread; nasal harmony is traditionally described as leftward spreading (towards the beginning of

<sup>2</sup> We are agnostic with respect to the theoretical treatment of the nasal feature as privative or equipollent; however, the former seems to cohere better with the data and analysis that we will present in this paper.

a word) or rightward spreading (towards the end of a word). One of the most studied cases of nasal spread comes from Guaraní (see e.g., Lunt 1973; Tonhauser 2006; Walker 1999). In Guaraní, nasalization has been described as spreading leftward from stressed nasal vowels, which typically occur in the ultimate syllable at the word level (see Example (1)).

- (1) Guaraní (Price & Stewart 2013)<sup>3</sup>  
*Curapepe /kurape'pẽ/ → [kûrãpẽ'pẽ] 'pumpkin, gourd'*

The second involves the domain in which the process applies (e.g., within a segment, syllable, word, or phrase). Example (2) from Desano (Eastern Tukanoan) illustrates morphemic nasality where morphemes are composed of either nasal or oral segments. This means that minimal pairs do not differ based on a single segment but rather by the feature [NASAL] across segments (Kaye 1971: 1).

- (2) Desano (Kaye 1971: 1)  
*[ñõhsõ] 'kind of bird' vs. [johso] 'kind of lizard'*

The third concerns the behavior of the segments; different segments can either act as triggers, blockers, or targets of spread. The following examples are gathered from Walker (2011), but we reference the original sources. Example (3) shows a nasal stop acting as a trigger for rightward spread in Sundanese (Austronesian, Western Java), which targets vowels and glottal consonants. Example (4) shows a word-medial voiceless stop (/p/) functioning as a blocker in Applecross Gaelic (Goidelic, Scotland) which inhibits the rightward spread of nasality to the rest of the word. Both examples (3) and (4) also provide instances of targets. The sequence [ããã] is a target of nasalization in (3a), the final vowel ([ã]) in (3b), the sequence [iš] in (4a), and the sequence [i(n)iš] in (4b). However, in (3c) only the first vowel [õ] is targeted due to the following blocker [b].

- (3) Sundanese (Robins 1957)
- naian [nãããn] 'wet (ACTIVE)'*
  - kumaha [kumãhã] 'how?'*
  - ŋõbah [ŋõbah] 'change (ACTIVE)'*
- (4) Applecross Gaelic (Ternes 2006)
- [tʰišišpaxk] 'plate'*
  - [mĩniſtar] 'minister (clergyman)'*

Walker (2000) provides a hierarchy that predicts which classes of segments are most likely to adopt the [+NASAL] feature during a spreading event. This hierarchy nearly runs parallel to the sonority hierarchy, with the exception of laryngeals, with more sonorous segments more likely to function as targets (see Example (5)). Schourup (1972) also discusses a transparency hierarchy that predicts which class of segments are least likely to display the [+NASAL] feature but does not impede the transmission of the feature to other segments during a nasal spreading event. Example (6) is based on Cohn's (1993) generalization of Schourup's (1972) hierarchy.

- |  |                           |
|--|---------------------------|
| <p>(5) <i>Least likely targets</i></p> <p>Obstruent stops &gt; Fricatives &gt; Liquids &gt; Glides &gt; Laryngeals &gt; Vowels</p>     | <p><i>Most likely</i></p> |
| <p>(6) <i>Least likely blockers</i></p> <p>Obstruent &gt; r, l (Liquids) &gt; w, j (Glides) &gt; h, ? (Laryngeals) &gt; V (Vowels)</p> | <p><i>Most likely</i></p> |

<sup>3</sup> Glossing conventions and general representation are true to the cited source.

## 2.2 Measuring nasality and the Earbuds Method

Numerous techniques and methods exist for both imaging and analyzing nasality in human speech. For example, real-time magnetic resonance imaging (RT-MRI) (Narayanan et al. 2004), and x-ray imaging (Öhman & Stevens 1963) allow for precise real-time tracking of velum gestures through visual observation that can be accurately measured. A number of more invasive techniques also allow for observation of velum gestures such as nasoendoscopy (Benguerel et al. 1975), photonasography (PNG) (Ohala 1971), velotrace (Horiguchi and Bell-Berti 1987), and dual airflow systems as implemented in Cohn (1990). However, all of these methods have a common problem— they are impractical outside of a clinical setting. One alternative is measuring nasality with acoustic methods (e.g., P1-A1 & P0-A0), which have been developed by Chen (1996) and expanded on by Styler (2015). Despite such advances, this method does not allow for temporal measurements making it impractical for identifying velar movements and co-articulation effects.

Because of these issues, we opted for the Earbuds Method (Stewart & Kohlberger 2017), which is specifically designed for collecting nasal data from the field using a non-invasive technique with minimal equipment. The Earbuds Method is based on the principle of nasalance, a nasal to oral amplitude output ratio (Fletcher et al. 1974), but instead of collecting amplitude (intensity) readings from a nasometer or a ‘nasal olive’ (see e.g., Ohala & Ohala 1991), a pair of low impedance earbuds (headphones with silicon tips) are used. This method has the added benefit of being more consultant-friendly as there is no headgear with a bulky nasal-oral shield divider (nasometer) and nothing is being inserted in the nose (nasal olive); additionally, our consultants were all familiar with earbuds as listening devices that come included with most cell phones.

This technique involves placing one earbud directly under a nostril with the silicon tip facing upward, channeling air from the nostril directly toward the earbud diaphragm (Stewart & Kohlberger 2017: 50). The other earbud is held in place by the consultant at the corner of the mouth. The earbuds are then connected to a recording jack, which reverses the signal flow converting the earbuds to small microphones with independent channels (when set to stereo). Because earbuds are designed for unidirectional low volume output, unidirectional low-gain input is also observed when used as a microphone. This makes it possible to collect data from both the nasal and oral tracts with minimal interference.<sup>4</sup> After normalization of the intensity (dB) contours from each track, the relation can be quantified using the nasalance ratio, which represents the proportion of nasal to oral energy within the signal (Stewart & Kohlberger 2017: 59). This information provides accurate details about the amplitude, timing, and duration of nasal gestures (e.g., pre- and post-nasalization, nasal harmony, nasal leakage<sup>5</sup>, and coarticulation effects) (Stewart & Kohlberger 2017: 50), which is what we seek to support or call into question in the observed phonological patterns in Ecuadorian Siona.

However, this method is not without its limitations. For one, some cross-channel interference is unavoidable, which is why controlling the gain with the volume control on the recording device is vital. Additionally, constant observation is required to make sure the earbuds remain in place as they are held by the consultant. Another limitation is that the Earbuds Method does not provide detailed information about airflow like other aerodynamic methods (e.g., double-chambered masks and transducers) and is thus limited

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<sup>4</sup> Stewart and Kohlberger (2017) also provide instructions for adjusting the technique if cross-over is observed (p. 54).

<sup>5</sup> Stewart and Kohlberger (2017: 61) describe nasal leakage, with respect to the Earbuds Method, as brief moments of low-level amplification that stems beyond the baseline. This is because velum aperture can take place at varying degrees (e.g., velum height interacts with other articulators such as tongue height), therefore observable differences in the height of nasal waveforms and intensity curves can be indicative of nasal leakage (low-level intensity in the nasal track), allophonic nasalization (a gradient and opposing shift in nasal and oral intensity to or from the nasal segment), and phonemic nasalization (high nasal intensity above that of the oral intensity for inherently nasal segments or high nasal and oral intensity in inherently nasal vowels which make use of both tracts).

to the timing and duration of nasal gestures (Stewart & Kohlberger 2017: 50). Therefore, if robust airflow calculations are a primary goal, this method is inadequate. Additionally, because the oral and nasal tract have inherent differences with respect to amplitude output, earbud data require normalization to identify accurate timing and duration of gestures, which may not be ideal for researchers interested in raw pressure differences (e.g., in a clinical setting where obstructive pathologies like nasal polyps cause abnormal airflow or output pressure). The Earbuds Method, while new, has been used to analyze nasality in Maxakalí (Brazil) (Nevins & Coelho da Silva 2017) and Ahamb (Vanuatu) (Rangelov 2019) and is featured as a field method in Understanding Linguistic Fieldwork (Meakins et al. 2018). Figure 2 provides an image of the recording set up to capture data using the earbud methods.



Figure 2: This image shows the recording set up using the Earbuds Method with one earbud directly under the nose and the other at the corner of the mouth.

### 3 Siona phonology

The general phonological analysis of Ecuadorian Siona briefly presented in this paper is based on the phonological sketch in Bruil (2014), which was based on a 74-minute corpus recorded in 2012 with a Marantz PMD620 recorder and a Sennheiser headset PC131. This analysis was checked using the 124 minutes audio corpus of (semi-)spontaneous monologues and conversations recorded in the period of June 2010-August 2011 with the Marantz PMD620. Additionally, various details from the analysis were verified using a video corpus of almost 46 hours of (semi-)spontaneous speech, of which almost 33 hours were transcribed and translated to Spanish. These data were recorded in the period of 2014 and 2015 using a SONY Handycam NEX-VG20EH and a Røde stereo video microphone. The full 2010-2011 and 2012 corpora are deposited at the ELAR. The deposit of the 2014-2015 video corpus is still in progress (Bruil 2015). In this section, we provide some background to Siona's phoneme inventory, phonotactics, and the role that morphology plays within this system.

#### 3.1 Consonants

The Siona phonemic consonant inventory consists of 18 consonants as can be observed in Table 1. Siona contains two phonemic nasal consonants /m, n/. Unlike in Eastern Tukanoan, these nasal segments are phonemic and not allophones of the oral stops as will be illustrated in §5. Additionally, in nasal spreading events, the nasal consonants [ñ, ũ, ñ] also appear in Siona.

Table 1: The phonemic consonant inventory of Ecuadorian Siona

		LABIAL	CORONAL		DORSAL		LARYNGEAL	
		Bilabial	Denti-alveolar	Palatal	Velar		Glottal	
					plain	round	plain	round
Nasal		m	n					
Plosive	Plain	p	t		k	k <sup>w</sup>		
	Laryn.	ꝑ	ꝑ		ꝑ	ꝑ <sup>w</sup>	?	
Fricative	Plain		s				h [h̚]	h <sup>w</sup>
	Laryn.		ꝑ					
Affricate				tʃ				
Approximant		w [w̚]		j [n̚]				

Siona contains two series of oral stops: a plain series consisting of /p, t, k, k<sup>w</sup>/ and a series of laryngealized stops that are transcribed as /p, ꝑ, ꝑ, ꝑ<sup>w</sup>/. This laryngealization is realized as creakiness on the first half of the following vowel as Ecuadorian Siona often lacks complete closure resulting in partial creaky voice. However, speakers show variation with respect to the intensity and frequency of this phenomenon. These laryngealized stop consonants are only found in word initial position; in word-internal positions /p, ꝑ/ are, generally, realized as [β, r] respectively.

(7) Ecuadorian Siona (Bruil 2014: 90)<sup>6</sup>

- a. paë-ye [pai.je] (plain)  
scare.off-CLS.GEN  
'to scare off'
- b. ba-ye [pa:je] (creak)  
have-CLS.GEN  
'to have'
- c. tëtë-ba [t̚ihtiβa] (word internal)  
riverbank-CLS.WALL  
'riverbank'

The velar stops /k, k<sup>w</sup>/ are not found in word internal position, except in compounds. In these constructions, /ꝑ, ꝑ<sup>w</sup>/ are realized as voiced stops ([g, g<sup>w</sup>]). The reason that these laryngealized consonants are not found in word internal position is due to a historical sound change in which /ꝑ, ꝑ<sup>w</sup>/ were deleted in Ecuador, at least intervocally, yet preserved (but voiced) in Colombia.

## (8) Colombian Siona (Wheeler 1987: 96)

- bone-guë [bõg̚si-gi]  
young-CLS.ANIM.M  
'young man'

<sup>6</sup> We decided to use the Ecuadorian Siona orthography when we represent an example from the language, because this is the way in which the Siona community prefers to see their language represented. The plain stops are represented as <p, t, c/qu, cu/quü> in the Siona orthography, following the Summer Institute of Linguistics orthography that was created by Mary and Orville Johnson and that is still generally used within the Siona communities in Ecuador. In this orthography, the laryngealized stops are represented as <b, d/r, g, gü>. The glottal stop is represented as <>. The sibilant /s/ is also represented as <s> and laryngealized sibilant /ꝑ/ is represented as <ts>. The glottal fricative /h/ and its labialized counterpart /h<sup>w</sup>/ are represented as <j, ju> respectively. The glottal fricative /h/ in coda positions, which is alternatively analyzed as preaspiration, is not represented in the Siona orthography. The affricate /tʃ/ is represented as <ch> and the approximants /w, j/ are represented as <hu, y> respectively. The vowel phonemes /i, i, u, e, o, a/ are represented as <i, ē, u, e, o, a> and nasality is represented with a *minus sign below diacritic*: <í, ē, ú, é, ó, á>. Long vowels i.e., vowels that consist of two morae, are represented as a single vowel.

- (9) Ecuadorian Siona  
 b<sub>os̥e</sub> [pō̥̃si-i]  
 young-CLS.ANIM.M  
 ‘young man’

The glottal stop may be realized as a full closure in careful speech, albeit surrounded with some creakiness (i.e., a creaky-voiced glottal approximant). However, it is more commonly realized as creakiness on the adjacent vowel(s) and none of the tokens recorded using the Earbuds Method revealed a glottal stop with complete closure. The distribution of the glottal stop is very different from that of the other stops. In word initial position, it is used in free variation with vowel-initial stems and is therefore not analyzed as a phoneme (e.g., *airo* [airo] or [airo] ‘forest’); nonetheless, intervocally, it is used contrastively (e.g., *ma* [ma:] ‘macaw’ vs. *ma’ā* [m<sub>a</sub>q<sub>a</sub>] or [m<sub>a</sub>?<sub>a</sub>] ‘path’). Additionally, the glottal stop is one of only two consonants (/?, h/) that can occur in a coda position (e.g., *hua’ti* [wa?.ti] or [w<sub>a</sub>.ti] ‘machete’). Other consonants are not found in this position.

Siona contains four phonemic fricatives: the plain sibilant /s/, its laryngealized counterpart /s̥/, and /h/ along with its labialized counterpart /hʷ/. The phonemes /s, s̥, hʷ/ are restricted to onset positions, whereas /h/ can occur in both onset and coda position. Additionally, /s, s̥, hʷ/ are restricted to word initial position. In word internal position there is neutralization of the plain versus laryngealized /s/. Evidence for this neutralization comes from the loss of post-glottalization in /s/ when it is found in the second part of a compound.

An additional note needs to be made about the codas /?, h/. Other Tukanoan languages show a similar distribution of these two glottal consonants, however in coda position they are not always analyzed as phonemic segments. For instance, Stenzel (2007) analyzes the glottal stop in Kotiria as a suprasegmental feature of the stem. Although there are some differences between the Siona and the Kotiria system, this is an analysis that is worthwhile to explore for Ecuadorian Siona as well. As for the coda /h/, it is generally analyzed as a regular phonological process: a voiceless consonant in the onset of the second syllable in a disyllabic foot is generally preaspirated: CVCV → CV<sup>h</sup>CV, as found in Colombian Siona (Wheeler 1987), Ecuadorian Sekoya (Johnson & Levinsohn 1990), Piratapuyo, Tukano, Desano, Tuyuka, Siriano, and Kotiria (Stenzel 2007: 355). In Ecuadorian Siona, the coda /h/ can generally also be analyzed as the regular phonological process of preaspiration of the following voiceless consonant. However, there are a few cases of preaspiration before /n/ in Ecuadorian Siona that cannot be analyzed as a phonological process. Therefore, coda /h/ is phonologically presented as a coda /h/. Phonetically, however, it is represented as preaspiration [hC], when it is realized as a result of the phonological process CVCV → CV<sup>h</sup>CV (see Bruil (2014: 103-106) for more discussion on this phenomenon).

Additional phonemic consonants in Siona are the affricate /ʃ/ and the approximants /w, j/. These three phonemes are found in onset positions both word initially and stem medially. In addition, the affricate /ʃ/ does not occur in the onset of inflectional suffixes, whereas the use of the approximants /w, j/ is frequent.

### 3.2 Vowels

The phonemic vowel inventory in Siona consists of 6 oral vowels and 6 nasal counterparts, as shown in Table 2. This vowel system with six phonemic vowel qualities is common in Tukanoan languages (Barnes 1999). The mid vowels /e, ē, o, õ/ are often realized as open-mid vowels, [ɛ, ē, ɔ, õ] and the high central vowels /i, ï/ are often realized as mid-central vowels [ø, õ].

Table 2: The phonemic vowel inventory of Ecuadorian Siona (adapted from Bruil 2014: 87)

	+FRONT		-FRONT			
			-ROUND		+ROUND	
	-NASAL	+NASAL	-NASAL	+NASAL	-NASAL	+NASAL
High	i	ĩ	ɨ	ɿ	u	ũ
Mid	e	ẽ			o	õ
Low			a	ã		

Most of these vowels can be combined as vowel sequences, but there are some constraints due to assimilation processes. The high vowels /i, ĩ, ɨ, ɿ/ seem to be less stable than the other vowels and undergo various processes of assimilation when combined with other vowels. For instance, the high front vowels /i, ɨ/ undergo complete assimilation when they are combined with the mid front vowels /e, ẽ/. The high central vowels /ɨ, ɿ/ undergo complete assimilation when combined with the high vowels /i, ĩ, u, û/ and partial assimilation when combined with the mid vowel /e, ẽ, o, õ/ (e.g., /e+i/ → [ei] & /o+i/ → [ou]).

### 3.3 Phonotactics & morphology

The syllable structures that are attested in Siona are monomoraic V, CV, CVC (codas are non-moraic), and bimoraic CVV. A bivocalic syllable can either consist of a long vowel or a vowel sequence. There are various restrictions for consonants: for instance, tautosyllabic consonant clusters are not allowed in the language, the coda can only be filled by a glottal consonant /ʔ, h/, and codas only occur word-internally. Further restrictions are imposed on syllables due to the bimoraic stem constraint in the language. This means that a stem either consists of a bivocalic syllable or of two monovocalic syllables.<sup>7</sup> Possible stem structures are: (C)VV, (C)VCV, and (C)VCCV. There are some roots that are monomoraic, but they show divergent behavior to bimoraic stems (Bruil 2014: 227-233). Stems with more than two morae seem to, at least historically, be multimorphemic.

Bound morphology also seems to be subject to various restrictions. For example, Tukanoan languages generally only show suffixes.<sup>8</sup> Additionally, most highly inflectional suffixes consist of either a vowel (V) or a consonant-vowel sequence (CV). As a result, in some cases, a suffix that consists of a single vowel can lead to the deletion of a root-final vowel to avoid the formation of a vowel sequence. Yet, in other cases, single vowel suffixes may produce a vowel sequence. For instance, the derivational morphemes that express two types of causatives on verbs *-a* and *-o* generally cause a reduction of the root: the final vowel of a bimoraic verb is deleted. Other morphemes consisting of only a vowel, such as the portmanteau verbal inflection *-o* and *-i*, show varying behavior depending on the phonological processes of assimilation that were described in the previous section.

## 4 Method

The Earbuds Method (Stewart & Kohlberger 2017) was used to provide justifications for the phonological patterns of nasality described in this study. We chose this method since we gathered the data under non-laboratory conditions at the community where the language is spoken. This method also provided the consultants with a higher overall level of comfort compared to other methods used to collect nasal data. The Earbuds Method captures the relative intensity of speech sounds as measured independently through the nasal and oral cavities. After normalizing the data, relative differences in amplitude (Pa) can be assessed visually by comparing the nasal and oral waveforms and quantified through a nasal to oral intensity (dB)

<sup>7</sup> The glottal codas are not weighted as a mora.

<sup>8</sup> There seem to be two verbal prefixes *se-* and *de-* in the language, as was pointed out by Vallejos & Schwarz (2016) for the highly related language, Sekoya. However, these prefixes are not very common in Siona.

ratio (essentially a measure of nasalance; see the thick orange/ green line in each figure's image).<sup>9</sup> Results provide information about the amplitude, timing, and duration of nasal and oral gestures. These results are then used to support or call into question the observed phonological patterns involving nasality in Siona, including inherent nasal segments and nasal harmony (targets, triggers, blockers, opaque segments, & rightward and leftward spreading).

#### 4.1 Participants

Thirteen consultants, nine women and four men, participated in this study. All consultants were born and raised in Sototsiaya or one of its surrounding communities and all were native speakers of Siona. The age of the consultants ranged from 16 to 75 and the majority had either a primary or secondary education and #04 was in his first year of university. Consultants #2, #4, #5, #7, #10, #12, and #13 were considered by the authors to have 'clearer' speech and therefore examples from these consultants appear more frequently than others in the text; however, all examples were compared with other consultants to support the findings in this paper. Consultants were monetarily compensated for their time and the minor (#13) was accompanied by his parents who were paid for his time. Table 3 summarizes key information regarding the consultants in this study.

Table 3: Demographic information of the Siona consultants from this study

Consultant Code	Gender	Age	Education
01	F	29	Secondary
02	M	20	Secondary
03	F	75	Primary
04	M	30	University
05	F	33	Secondary
06	F	53	Primary
07	F	57	Primary
08	F	38	Secondary
09	F	47	Primary
10	M	18	Secondary
11	F	18	Secondary
12	F	46	Primary
13	M	16	Secondary

#### 4.2 Materials

Acoustic data were collected by the authors in the community of Sototsiaya, Ecuador in July of 2016. Data were elicited using a wordlist containing 150 words and phrases, including minimal pairs, based on examples from Bruil (2014). The wordlist was designed to gather examples of nasal harmony (both leftward & rightward), morpheme boundaries, and segments identified therein as transparent, triggers, targets, and blockers. Examples also included all phonemic nasal consonants (/n, m/) in onset (including word-initial) position and phonemic nasal vowels (/ĩ, ñ, ē, õ, ū, ã/) in word-initial, -medial, and -final nuclear positions. The total number of tokens collected was 614 as not all participants recorded all the words. However, there was even coverage of all the items on the wordlist as the stopping point for one speaker was the starting point for the next (i.e., gaps were evenly distributed across the participants).

<sup>9</sup> However, it is important to note that because nasal vowels are produced simultaneously with both oral and nasal tracts, the ratio line within a single word may be less useful than a relational comparison of ratio lines with other purely oral vowels either within the same utterance or across utterances, as mentioned in §2.2.

The wordlist data were recorded in 16-bit Waveform Audio File Format (WAV) with a sample rate of 44.1 kHz using a pair of low impedance earbuds (27 ohms). The earbuds were connected to a ZOOM H4n digital recorder set to record in stereo.

### 4.3 Procedures

For the elicitation sessions, the authors explained, in Spanish, to the consultants the purpose of the study and what was required of the Earbuds Method. This involved asking the consultant to hold one earbud immediately below one nostril with the tip facing upwards while keeping the other earbud at the edge of the mouth facing forward. We demonstrated the positioning and once the consultants were ready, we asked them to provide translations of the words and sentences into Siona.<sup>10</sup> Consultants were asked to not over enunciate the words and to try and speak at a normal rate. We provided each consultant with approximately half of the list per session as we rotated through the list. We often asked the consultants to repeat their translations several times. Consultants were also encouraged to consult with other speakers in case any doubt arose.

## 5 Nasality in Ecuadorian Siona

In this section, we provide acoustic measurements of nasality in Siona and a phonological analysis based on these measurements. Nasality in Siona has been described (Bruil 2014: 124–129) as operating on various levels: at the segmental level, at the syllable level, and at the word level. Firstly, there are two phonemically nasal consonants [m, n]. Additional segments that can be analyzed as nasal phonemes are the vowels: /i, ï, û, ë, ð, ã/ as these are frequently the only nasal segments in a word.

Additionally, nasality operates on a suprasegmental level spreading from the nasal segments /m, n, ï, û, ë, ð, ã/. The language shows spread in two directions. The domains in which these processes operate are distinct: rightward nasal harmony operates at a word level and leftward nasal harmony operates only within the syllable. The most salient example of leftward nasal harmony involves the plural suffix [-ã], which is added to monosyllabic inanimate classifiers in order to pluralize the word. Vowels preceding /ã/ always undergo nasalization in addition to target consonants /w, j/ [w̄, j̄]. Since this is the only suffix consisting of only a nasal vowel, there are no counterexamples in which nasality does not spread leftward. As expected, the blockers, consisting of the stops, affricate, and sibilants, do not nasalize in this context and do not allow nasality to spread to the preceding syllable. An additional case of leftward nasal spread is the root-internal nasalization of /w, j/ [w̄, j̄]. Nasal segments and nasal spread are discussed in §5.1.

Targets for nasality include the vowels /i, ï, u, e, o, a/, the approximants /w, j/, and the glottal fricative /h/. The glottal stop is also a target for nasalization since it is realized as laryngealization. These types of segments will be discussed in §5.2. Even though nasality can spread from the beginning to the end of a word, this rarely happens, because many consonants are blockers for nasal harmony: all stops, the affricate, and the sibilants block nasality from spreading rightward: /(p), t, k, kʷ, p̄, t̄, (k̄, kʷ̄) ŋ, s, (s̄)/.<sup>11</sup> The behavior of blockers will be discussed in §5.3.

The figures in this section were created using the R scripts provided in Stewart & Kohlberger (2017). However, instead of having separate graphs for the waveform and ratio results, both were combined for a more succinct presentation. Each figure contains the transposed nasal (red) and oral (blue) waveforms with

<sup>10</sup> By asking for translations instead of saying the target words/ phrases ourselves in Siona, we avoided influencing the responses through possible mirroring effects as we are not native speakers of the language. If a word was translated differently from the target we had in mind, it was simply excluded from analysis unless it had nasal phenomena that merited further investigation.

<sup>11</sup> The phonemes represented between parentheses rarely occur word-internally due to phonological changes. They are found word-internally in compounds and do not allow nasal spread in those words. However, this could also be due to the inherent orality of the second stem in the compound.

the nasalance ratio data presented as a thick green (nasal)/ orange (oral) line. In addition, transposed nasal (red) and oral (blue) intensity (dB) output is displayed for an additional level of analysis. Nasal events in the figures are indicated by the nasalance line over the 50%-mark (green > 50%, orange < 50%) and prominence of the red (nasal) waveform above the blue (oral) waveform, which may take place on or near a single segment or across various segments. Since nasal vowels make use of both the nasal and oral tracts during speech production, often both the nasal and oral waveforms will have similar levels of prominence (see e.g., [-w̄iā] in Figure 10).

### 5.1 Nasalizers

Nasalizers (triggers) in Siona are inherently nasal segments that trigger nasal spreading from all positions (word-initial, word-internal, and word-final). The segments /m/ and /n/ are phonemically contrastive with /p, [p, b, β]/ and /t̄ [t, d, r]/.<sup>12</sup> The /m/ versus /p/ contrast can be observed in Figure 3 & Example (10).

- (10) a. bai /p̄ai/ → [bāi]  
           ‘people’
- b. mai /mai/ → [māi]  
           ‘we.INC’

Additional examples of /b/-/m/ minimal/near-pairs are included in example (11):

- (11) a. bēi /p̄i/ → [p̄i] (oral)  
       /p̄i-i/<sup>13</sup>  
       be.angry-S.M.PRS.DEP  
       ‘when he was angry’  
       vs.  
       mē'ë /mi?i/ → [m̄i?i] (nasal)  
       ‘you.2S’
- b. bosē /p̄ohsi/ → [p̄ōs̄i]<sup>14</sup> (oral)  
       ‘young’  
       vs.  
       mo'se /mo?se/ → [m̄o?se] (nasal)  
       ‘day’

<sup>12</sup> Nasal stops and laryngealized stops are also contrastive with plain stops. However, the rarity of /p/ made it difficult to find words containing /p/ that contrast with /m/. The word /pūhpaji/ ‘I am smoking’ shows an example of a plain stop followed by a nasal vowel contrasting it with N̄V. It should also be known that, unlike the laryngealized stops, the plain stops do not have any allophonic variants.

<sup>13</sup> The central vowel /i/ coalesces with /i/ when it follows the front vowel and is realized as [i].

<sup>14</sup> The voiceless sibilant /s/ in /p̄ohsi/ is preaspirated. Phonemically, preaspiration is analyzed as a coda /h/ as discussed in §3.3. Preaspiration is not represented in the Siona orthography.

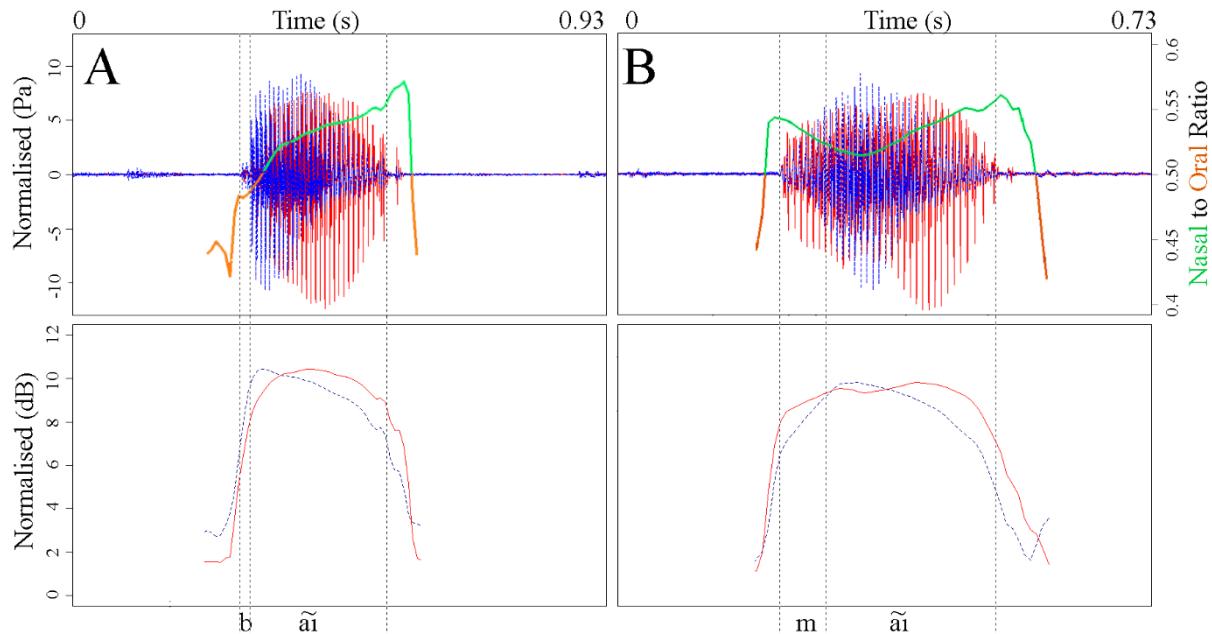


Figure 3: Minimal pairs *bai* [bāi] 'people' (left) vs. *mai* [māi] 'we.INC' (right). Both the waveform and intensity curve in Figure B reveal /m/ as the phoneme responsible for nasal spread rather than a target affected by a nasal spreading event. Figure A represents a word-initial oral /b/, which is not affected by the subsequent nasal event. These examples place /b/ and /m/ in contrastive distribution. Consultant #13.

The /n/ versus /t/ contrast is illustrated in Figure 4 & example (12):

- (12) a. dëjo /t̪̥ho/ → [d̪̥hõ] 'wife'  
       b. nëca-ye /nihkaje/ → [n̪̥kaje] stand-CLS.GEN 'to stand'

Additional examples of /d/-/n/ minimal/ near-pairs are included in example (13):

- (13) a. daë-ni /t̪̥ini/ [t̪̥iñi] (oral)  
          pull-SS.PST  
          'pulling'  
          vs.  
          na'i-ni /nã?ini/ [nã?iñi] (nasal)  
          become.evening-SS.PST  
          'becoming evening'  
       b. dëme-ñe /t̪̥imeje/ → [t̪̥imẽñe] (oral)  
          bend.over-CLS.GEN  
          'to bend over'  
          vs.  
          nëca-ye /nihkaje/ → [n̪̥kaje] (nasal)  
          stand-CLS.GEN  
          'to stand'

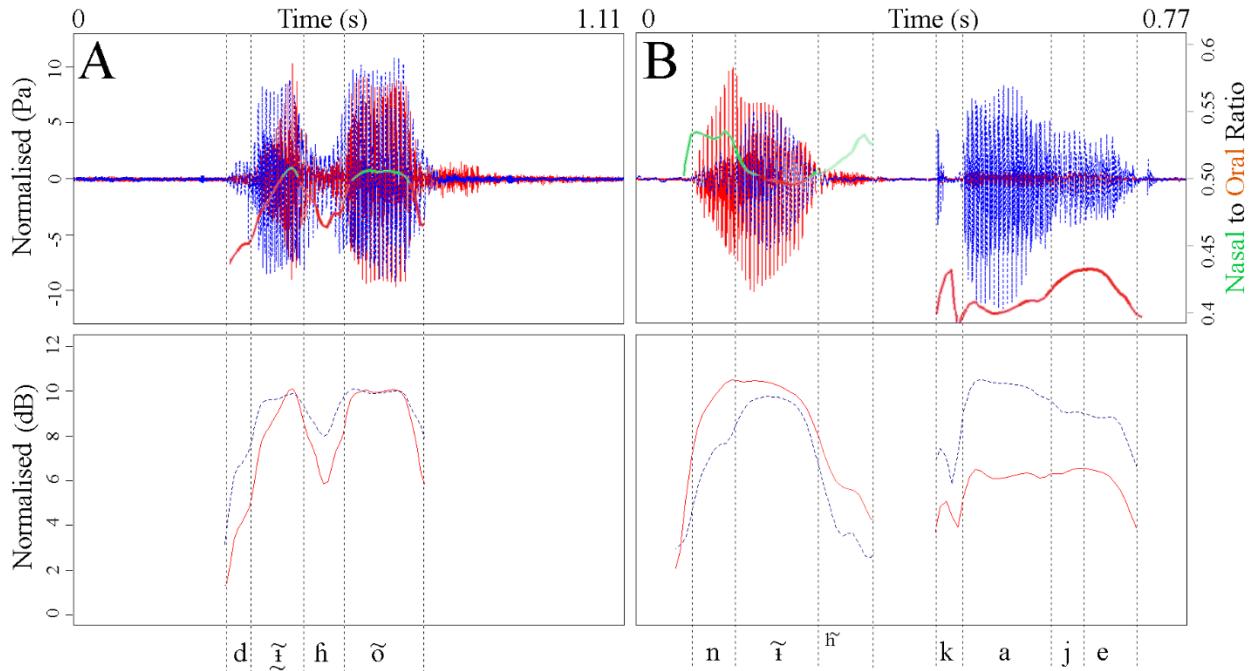


Figure 4: Near-minimal pairs and *dëjo* [d̪iħõ] 'wife' and *nëkaje* [n̪iħkaje] 'to stand'. Both the waveform and intensity curve in figure B (produced by Consultant #7) reveal /n/ as the phoneme responsible for nasal spread rather than a target affected by a nasal spreading event. Figure A (produced by Consultant #3) represents a word-initial oral /d/, which is not affected by the subsequent nasal event initiated by /i/. These examples place /d/ and /n/ in contrastive distribution.

Furthermore, oral-nasal vowel pairs are also found in contrastive distribution. These include: /i/, /i̪/, /u/, /e/, /o/, and /a/ and their nasal counterparts, /ī/, /i̪/, /ū/, /ē/, /ō/, and /ā/. These nasal counterparts can function as independent phonemes not only because of their contrastive distribution (e.g., *ca-co* /ka:ko/ ‘she says’ vs. *cai-co* /käiko/ ‘she sleeps’), but also because the nasal series can trigger nasal harmony (see e.g., Figure 12 for /ū/, Figure 13E for /ō/, and Figure 13B for /ā/).

## 5.2 Targets

Targets, as opposed to nasalizers, undergo nasalization during a nasal spreading event, but are not responsible for instigating the spread. In §4.1 we showed that when the vowels /i/, /i̪/, /u/, /e/, /o/, /a/ initiate nasal spread, they need to be analyzed as independent phonemes from their oral counterparts. However, at the same time, oral vowels can also undergo allophonic nasalization during a nasal spreading event. This is best illustrated with an example of nasal spread across morpheme boundaries.<sup>15</sup> Figure 5 and example (14) illustrate this with the suffix *-ye* [je] attached to the word *mëi* [m̪i] which is nasalized by the word-initial [m]. In this case, the suffix undergoes nasalization to *-ñe* [n̪e], without a change in meaning; also providing evidence of rightward spread.

- (14) *mëi-ñe* /m̪iijñe/ → [m̪iijn̪e]  
go.up-CLS.GEN  
'to go up'

<sup>15</sup> Differently from Máihíki (Sylak-Glassman et al. 2014), Siona shows nasal spreading across morpheme boundaries.

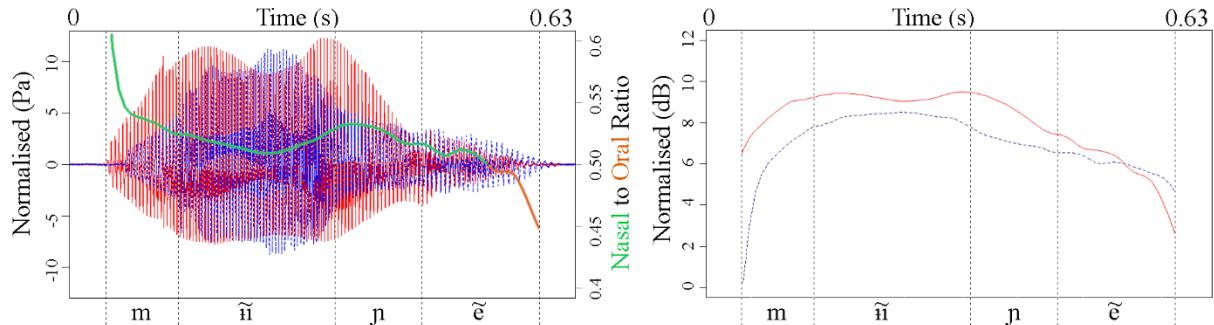


Figure 5: The Siona word *mëiñe* [m̩iñe] 'to go up'. Rightward spreading nasal harmony begins on the [m] and then passes the clitic boundary -ye nasalizing the palatal approximant /j/ to [n]. Consultant #3.

An example of this same suffix in its oral form is illustrated in Figure 6 where it appears as -ye [je] when attached to the word *sehuo* [sewo]; a word containing no nasal segments.

- (15) sehuo-ye /sewoje/ → [sewoje]  
accept-CLS.GEN  
'to accept'

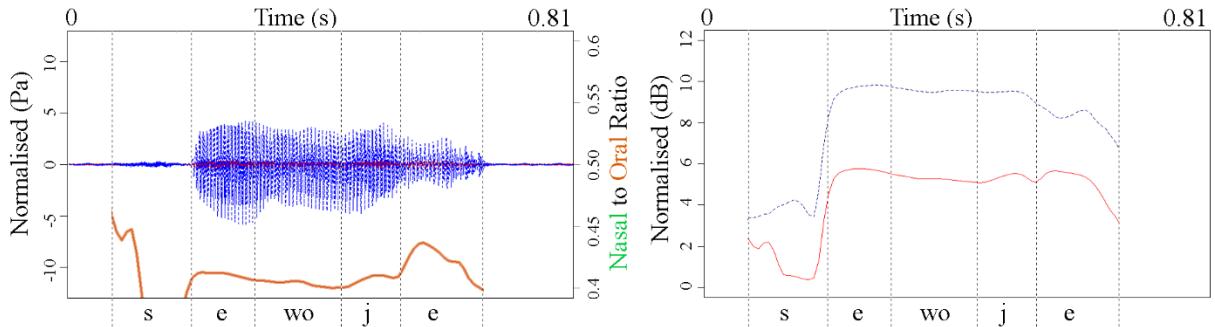


Figure 6: The Siona word *Sehuoye* [sewoje] 'To accept'. Contrarily to Figure 5, in this example the clitic '-ye' is not affected by nasal harmony and maintains its oral form /je/. Consultant #12.

Additional examples of /j/ → [n] are included in example (16):

- (16) a. tsia-ya /siaja/ → [siaja]  
river-CLS.RIVER  
'river'  
vs.  
bi'a-ña /p̪i?aja/ → [p̪i?añā]  
bird-CLS.RIVER  
'bird river'
- b. sai-yë /saiji/ → [saiji]  
go-N3S. PRS.ASS  
'I'm going'  
vs.  
sai-ñë /säijë/ → [säijñ]  
pay-N3S. PRS.ASS  
'I'm paying'

Two possible interpretations can be drawn from the behavior of glides, /j/ (<y>) and /w/ (<hu>). In the first, oral and nasal glides are considered in contrastive distribution, and therefore could be considered as phonemic nasalizers (see Examples (16), (17), & (18) with the underlying representations in slashes and the surface form in brackets).

- (17) ñañë /jāji/ → [ñāñí] 'moon'

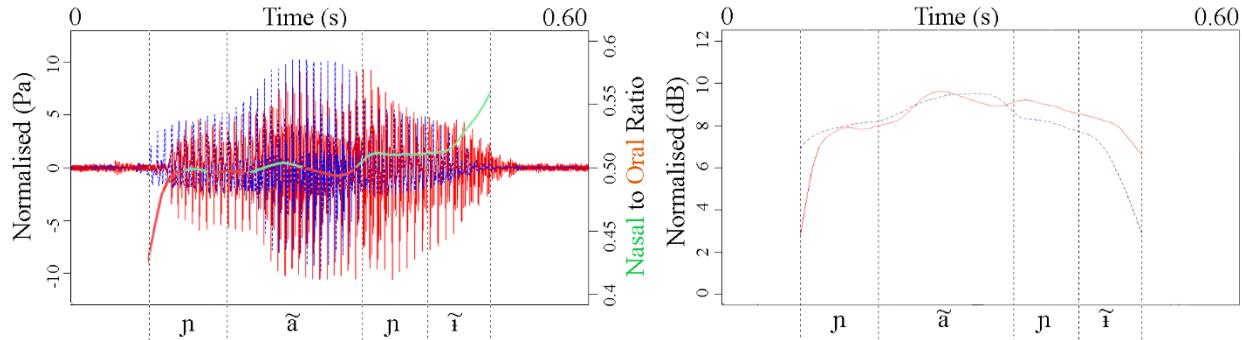


Figure 7: The Siona word ñañë [ñāñí] 'moon'. Consultant #2.

- (18) huañumi /wājumi/ → [wāñumí] 'anaconda'

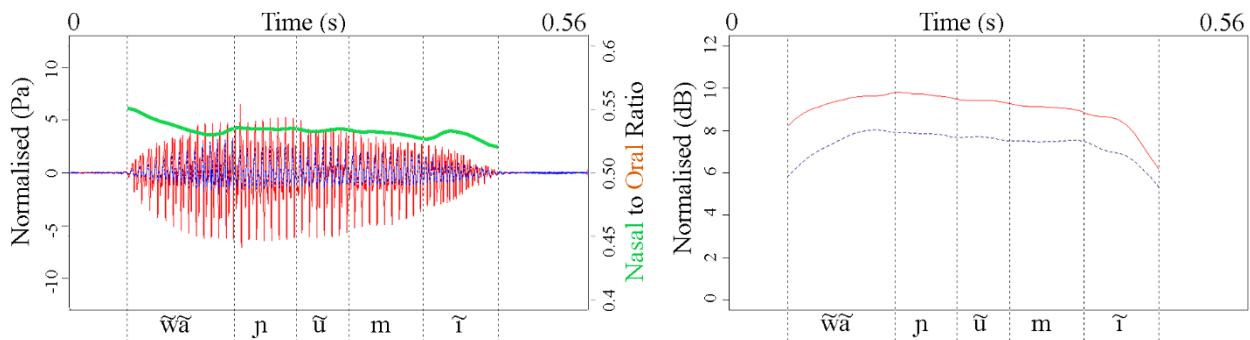


Figure 8: The Siona word huañumi [wāñumí] 'anaconda'. Consultant #3.

In this first interpretation, the rightward nasal spreading seen in (17) and (18) is similar to the nasal harmony spread seen in the vowels, which continues throughout a word until its end or a blocker is encountered (see Section 3.1). In (17), the first [j̄] would function as a nasalizer that prompts a nasal spreading event across the word indicating that [j̄] could be phonemically distinct from /j/ since no trigger is causing /j/ to become [j̄] in this environment. More evidence for analyzing nasal glides as triggers is observed in (18) where [w̄] initiates the nasal spread throughout the word from the word-initial position. Moreover, /w/ and [w̄] have near minimal pairs as seen when comparing (18) and (19) which shows an example of oral /w/ in word-initial position + /a/ (as opposed to nasal [w̄] in word-initial position + /a/ in (18)), with no evidence of nasalization or nasal spreading within the word.

- (19) huahua-si-quë /wawasikhki/ → [wawasi<sup>h</sup>kí]  
float-CMPL-CLS.ANIM.M  
'the one who had been floating'

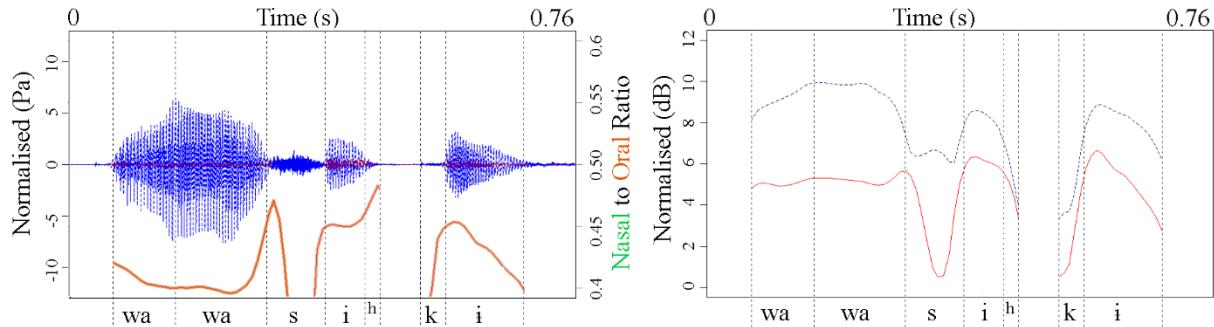


Figure 9: The Siona word *huahuasiquë* [wawasihki] 'the one who had been floating'.

However, we have yet to come across an example of a lexeme where oral /j/ or oral /w/ precede a nasal vowel. This leads to our second interpretation where glides preceding nasal vowels assimilate the nasal feature (similar to leftward spreading), possibly due to their high sonority. In this interpretation, Siona would contain contrasting oral-nasal syllables (e.g., /ja/-/jã/ and /wa/-/wã/). This provides evidence that spreading also takes place word-internally since [n] and [w̃] are nasal allophones of /j/ and /w/. Additional examples of oral-nasal glide-vowel syllable contrasts are included in example (20):

- (20) a. sa-huë /saawi/ → [sa:w̃i] (oral)  
take-N3S.PST.ASS  
'I took'  
vs.  
ne-huë /neewi/ → [ñe:w̃i] (nasal)  
make-N3S.PST.ASS  
'I made'
- b. ye'ye-huë /je?jewi/ → [je?jew̃i] (oral)  
learn-N3S.PST.ASS  
'I learned'  
vs.  
t̃eo-huë /t̃owi/ → [t̃o:w̃i] (nasal)  
weave-N3S.PST.ASS  
'I wove'
- c. mejahuë /mehawi/ → [m̃eh̃aw̃i] (oral)  
sand-CLS:CONTAIN  
'beach'  
vs.  
noca-huë /nohkawi/ → [ñoh̃kawi] (nasal)  
banana-CLS:CONTAIN  
'banana bunch'

Since there are no contrastive examples of the oral glides /j/ and /w/ with the nasal glides [n] and [w̃], we adopt the second possible explanation and analyze [n] and [w̃] as oral counterparts of /j/ and /w/, respectively. These glides may become nasal due to rightward or leftward nasal spread, either root-internally or crossing morpheme boundaries.

Another example of sonorous segments assimilating the nasal feature of a following nasal vowel are observed with the plural suffix [-ã]. This provides additional evidence that leftward spreading is only syllable-internal as [-ã] joins the nucleus of the preceding open syllable (forming a nuclear vowel sequence)

and passing along its [+NASAL] feature to all sonorous segments in the syllable, but not beyond it as observed in example (21).

- (21) do'ro-huë /tɔ.ro.wi/ → [dɔ̃.ro.wi]  
 basket-CLS:CONTAIN  
 'basket'  
 vs.  
 do'ro-huë-a/tɔ.ro.wiã/ → [dɔ̃.ro.wiã]  
 basket-CLS:CONTAIN-PL  
 'baskets'

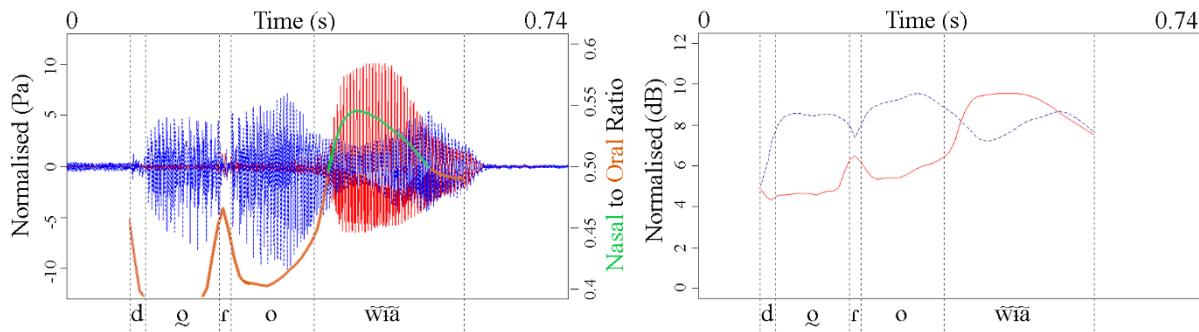


Figure 10: Transposed nasal (red) and oral (blue) waveforms with the oral to nasal intensity (dB) ratio (green/orange line) of the Siona word *do'rohuë-a* [dɔ̃rowĩã] 'baskets'. Leftward spreading (i.e., anticipatory nasalization) nasal harmony begins on [w] before reaching the inherently nasal target [ã] at the end of the word. In this case, nasal harmony is confined to the syllable containing the plural morpheme -*a* [ã].  
 Consultant #10.

From an aerodynamic standpoint, leftward spreading is better defined as anticipatory nasalization as the velum begins lowering on the onset of the syllable in anticipation of the nasal suffix -*a* [ã]. Figure 10 provides an example of the same word as in Figure 11 but in its singular form *do'rohuë*. In this example, the final syllable [wi], is completely oral along with the rest of the word.

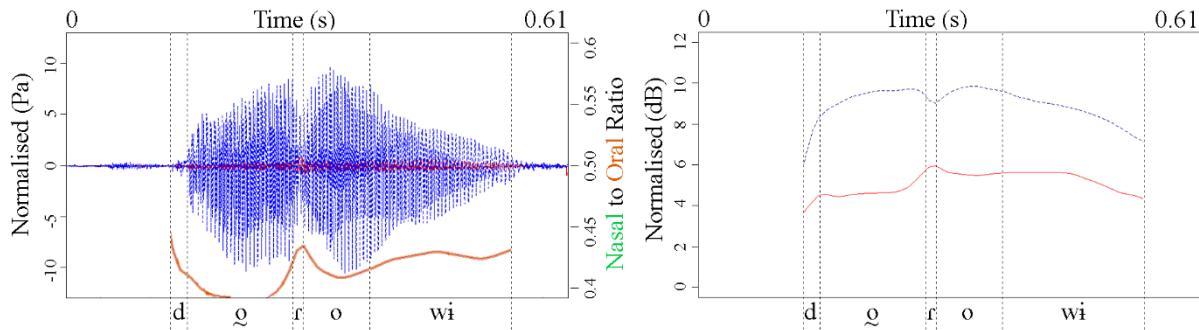


Figure 11: The Siona word *do'rohuë* [dɔ̃rowɪ] 'basket'. In contrast to Figure 10, the single word *do'rohuë* shown here does not contain any indication of nasality. This suggests that the plural morpheme -*a* [ã] (as seen in Figure 10) is indeed responsible for leftward spreading nasality. Consultant #10.

Therefore, the fact that the pluralizing suffix [-ã] is the only nasal segment in Figure 10 suggests that it is responsible for the leftward nasal spread throughout the ultimate syllable of the stem [dɔ̃rowi] and not the alternative—the spontaneous nasalization of [w] followed by rightward spreading into the already nasalized [-ã] suffix.

The only obstruents that do not have phonemic nasal counterparts are the glottal segments [h] and [ʔ], which only undergo nasalization if they are in the path of a nasal spreading event. A glottal stop becomes nasalized if it is realized as laryngealization rather than as a stop with full closure. If this is not the case, then the segment is transparent (i.e., ignored during nasal spreading). The word *ju-ju'i* 'he died' in Figure 12 contains both a nasalized /h/ ([h̩]) and a nasalized /ʔ/ (realized as [Ӄ] due to assimilation with the previous segment and lack of complete closure) which undergo this process triggered by the first nasal vowel [Ӄ].<sup>16</sup> This example also illustrates the difference between oral and nasal [h] where the first instance of this segment, in word-initial position, is realized as oral.

Figure 10 and Figure 12 also reveal two additional important aspects of nasal spreading in Siona, (i) nasal spreading only has a rightward trajectory within a word since the first [h] does not undergo nasalization before [Ӄ] (Figure 12), and (ii) leftward spreading is restricted to sonorous segments such as vowels and glides, henceforth referred to as *vocoids* (Figure 10).

- (22) *ju-ju'i* /h̩huʔi/ → [h̩h̩ūӃ]

die-3S.M.PST.ASS

'he died'

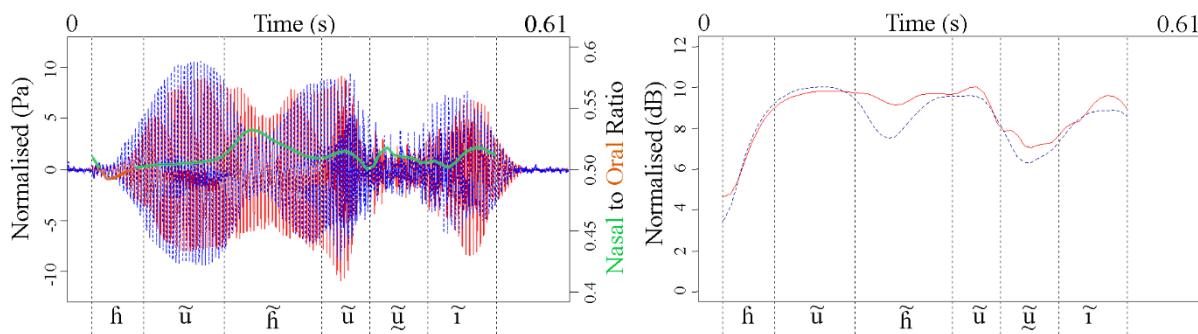


Figure 12: The Siona word *ju-ju'i* [h̩h̩ūӃ] 'He died'. Rightward spreading nasal harmony begins on the first [Ӄ] before reaching the final segment of the word three syllables away. In this example, nasality also crosses the *-ju'i* '3S.M.PAST.ASS' morpheme boundary. It should be noted that the glottal stop does not function as a blocker; instead, it manifests as nasalized creaky-voiced glottal approximant. Consultant #1.

Additional examples of /h/ and /ʔ/ as targets are included in example (23).

- (23) a. *ñaa-jë* /jääahi/ → [jää:h̩i] (nasal)

see-PL.PRS.DEP

'while we are seeing'

vs.

- séo-jë* /siohi/ → [siohi] (oral)

roast-PL.PRS.DEP

'while we are roasting'

- b. *ai-jë* /äih̩i/ → [äih̩i] (nasal)

eat-PL.PRS.DEP

'while we are eating'

<sup>16</sup> It should be noted, however, that /h/ does not always function as a target, as seen in Figure 4A, but in these rare cases it acts as a transparent segment and not as a blocker.

- vs.  
 yo'-jë /jo?hi/ → [jo?hi] (oral)  
 do-PL.PRS.DEP  
 ‘while we are doing’
- c. neji /nēēhi/ → [nē:hi] (nasal)  
 make-3S.M.PRS.ASS  
 ‘he makes’  
 vs.  
 deo-ji /teohi/ → [teohi] (oral)  
 be.good-3S.M.PRS.ASS  
 ‘thank you’

This means that the targets for nasalization in Siona include: /h/, /ʔ/, /w/, /j/, /i/, /i/, /u/, /e/, /o/, /a/, but only /i/, /i/, /u/, /e/, /o/, /a/ have phonemic nasal counterparts (i.e., function as nasalizers). These observations allow us to posit that leftward nasal spreading is restricted to the syllable containing the trigger (see e.g., Figure 10), and only affects targets that share the [+VOCOID] feature with the trigger (see e.g., Figure 10 & Figure 7). Restricting targets to highly sonorous segments such as vowels and glides also supports Walker’s (2000) hierarchy (see Example (5)) that predicts such sound classes are more likely to be targets. Additionally, no examples of leftward spreading affecting obstruents were identified within the data yet numerous examples showed oral obstruents before nasal vowels (see e.g., Figure 12, Figure 3, & Figure 13). This tendency is summarized in (24).

$$(24) \quad [+VOCOID] \rightarrow [+NASAL] \setminus \sigma \_ \tilde{V}$$

### 5.3 Blockers

Nasal spreading, or nasal harmony, in Siona can be blocked if the spread encounters any consonant that is not a glide ([w/j]) or laryngeal ([h/ʔ]). These include stop consonants and their allophonic variations (/p/, /t/, /k/, /p̪/, [p̪, b, β]/, /t̪/ [t̪, d, r/]), along with the fricatives (/s [s, ts]/). When a blocker is encountered during a nasal spread, the velum closes off access to the nasal cavity until the word either ends or a subsequent nasal segment is encountered.

- (25) a. pupu-yë /pūhp̪uji/ → [pū̩p̪uji]  
 smoke-N3S.PRS.ASS  
 ‘I am smoking’
- b. t̪ate-yë /t̪ah̪teji/ → [dā̩t̪eji]  
 plant-N3S.PRS.ASS  
 ‘I am planting’
- c. nēca-ye /nīhkaje/ → [nī̩kaje]  
 stand-CLS.GEN  
 ‘to be standing’
- d. jaø-bi /hāøpi/ → [hāøβi]  
 DEM.MED-SBJ  
 ‘he’

- e. *ao-re /ãote/ → [ãore]*  
food-OBJ  
'food'
- f. *cuena-si'i /kʷẽnasi'i/ → [kuẽnāsi]*  
dry-FUT.N3S.ASS  
'I am going to dry'

Figure 13 provides acoustic details of the velum gestures presented in the examples in (25). In Figure 13A - Figure 13C, the phonetically preaspirated<sup>17</sup> oral stop consonants [ʰp, ʰt, ʰk] impede nasal spread into the following segments as the velum raises during the closure phase. The pre-aspiration phrase preceding the closure in these examples shows a higher nasal to oral ratio, indicating the presence of nasality, which would suggest voiceless stops in a nasal spread are more precisely represented as [f̚p, f̚t, f̚k].

At first glance, it appears vowels may simply be devoicing or tapering off in energy as they transition into the closure phase of the subsequent stop; however, Figure 13D - Figure 13F with non-plain voiceless stops acting as blockers post-verbally, either show abrupt closure (Figure 13E) or remain voiced as indicated by the periodic wave cycles transitioning into the next segment. The /p/ phoneme in Figure 13D is realized as [β] and appears to maintain some degree of nasalization throughout the segment; a common trend in the data when /p/ undergoes spirantization. The negative trajectory of the nasal-to-oral ratio intensity curve in this example, might suggest the closing gesture of the velum does not have a fixed target or that its target is at the end of the segment. It should also be noted that the segments delimited as initial voiceless stops correspond to release phases and not the entire stop.

It is also worth emphasizing that because nasal vowels are produced from both oral and nasal tracts, they often contain similar levels of amplitude after normalization using the Earbuds Method. Therefore, vowels will often show a greater or lesser degree of nasality based on whichever tract receives greater output. In such cases, the ratio line within a single nasal vowel may be less useful than a relational comparison of ratio lines with other purely oral vowels or even with purely oral vowels in another word. For example, both /ũ/ and /u/ in Figure 13A, show substantially different ratio lines with the former clearly suggesting nasality and the latter clearly suggesting orality. However, the nasal vowels and vowel sequences in the remaining images in Figure 13 (A, B, C, D, E, F) show varying degrees of nasality according to the ratio line, with some hovering around the 50% mark (e.g., Figure 13C), others beginning below the 50% and overtaking it towards the end (e.g., the vowel sequences in Figure 13D, E, F), and vowels that do not surpass the 50% mark (e.g., Figure 13F).

One possible explanation is that nasality in the vowel sequences in Figures 13D and E does not start until the second half of the vowel because of a possible syllable break between the two vowels.<sup>18</sup> This syllabic analysis is also found in descriptions of other Tukanoan languages. For instance, Eraso (2015: 112-114) analyzes vowel sequences in Tanimuca as a disyllabic structure, referring to each vowel as the nucleus of a syllable. In figure 13F, the reason that [u] is not nasal is because it is part of the rounding of the velar /kʷ/. However, we still consider these nasal vowels as comparisons with purely oral vowels in Figure 13 still show a substantial difference in the ratio line in nasal production e.g., ([a] and [e] in Figure 13C). Additionally, it is worth noting that the 'nasal' vowel sequences in all the examples in Figure 13 may be more precisely described from a phonetic standpoint as oral-nasal vowel sequences, given that evidence of nasalization does not robustly appear until roughly the second segment of the sequence.

<sup>17</sup> Phonemically, the preaspiration is analyzed as a coda /h/ as discussed in §3.3.

<sup>18</sup> We are grateful to the editor for pointing this out to us.

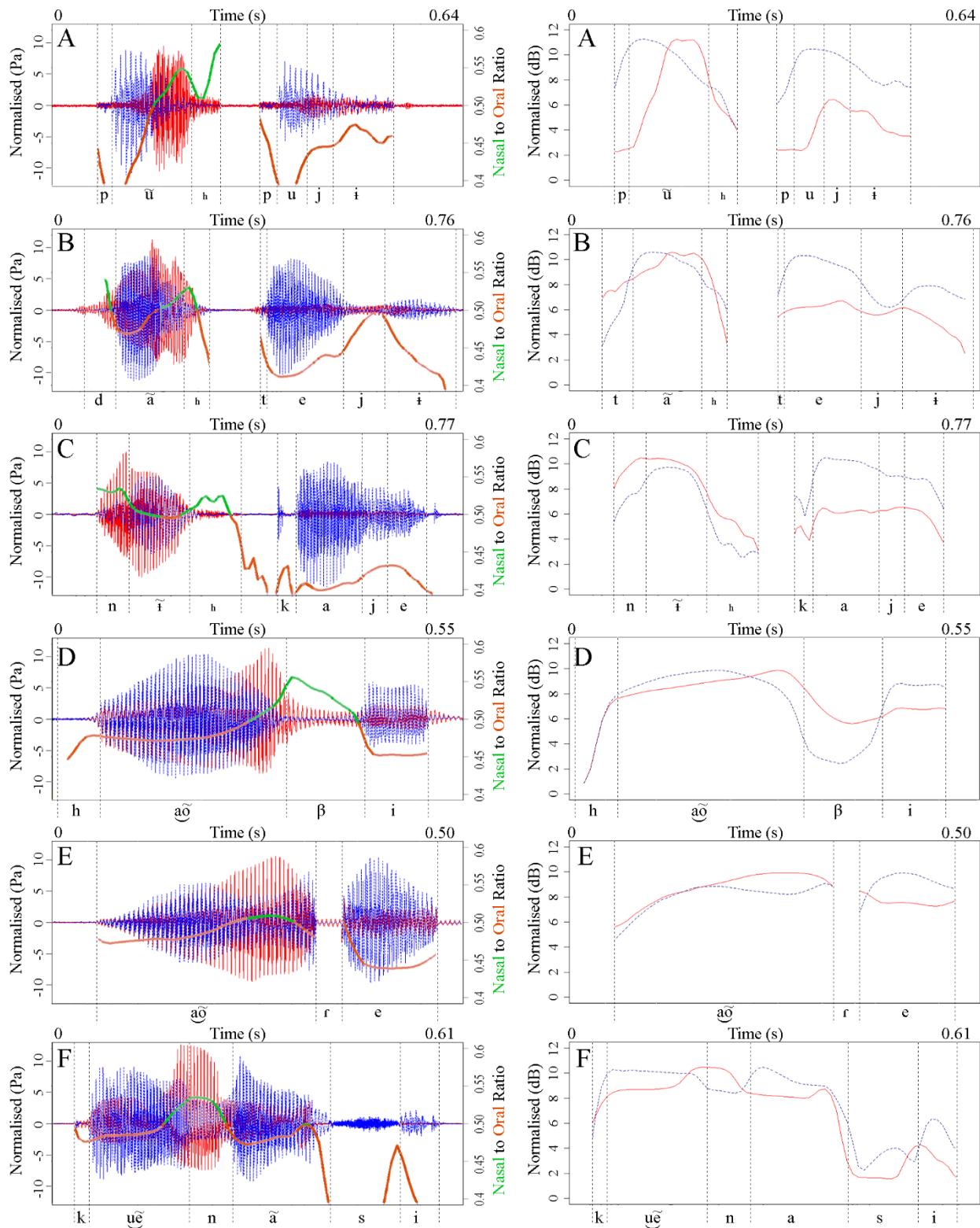


Figure 13: The Siona words provided in (25). Image A contains an example of the nasalizer [ñ] with its spread immediately blocked by the [p] segment in onset position in the following syllable. Image B contains an example of the nasalizer [ã] with its spread immediately blocked by the [t] segment in onset

position in the following syllable. Image C contains an example of the nasalizer [i] with its spread immediately blocked by the [k] segment in onset position in the following syllable. Image D contains an example of the nasalizer [aõ] with its spread through [β] until orality takes over. Image E with the nasalizer [aõ] shows its spread immediately blocked by the [r] segment in onset position in the following syllable.

Image F contains an example of the nasalizer [uė] with its spread blocked by the [s] segment in onset position two syllables away.

#### 5.4 Compounds and newly grammaticalized suffixes as blockers

There are a number of newly compounded lexical items in Siona, evidenced by the fact that (i) some forms still have lexical counterparts, (ii) many of these suffixes are bimoraic, like regular stems, whereas more grammaticalized suffixes are monomoraic, and (iii) when found as the initial consonant in the second part of a compound, laryngealized phonemes appear allophonically as voiced stops or fricatives just like in word-internal positions in non-compounded words (e.g., /p/ at the beginning of the second element of a compound is realized as /b/ or /β/). When nasal spread is present in these items, it ceases at the diachronic boundary between two historically distinct roots; no matter if the segment at the boundary would normally undergo nasalization (26). Similarly, newly grammaticalized suffixes also act like blockers of nasal spread. Example (27) contains the suffix *-hua'i* 'PLURAL', which combines with *Jaqē* 'he'.

- (26) sani-huesë-huë. /saniwesiwi/ → [san̩wesiwi]

go-N.REP-3S.M.PST.ASS  
'he left for good'

- (27) jaë-hua'i /ha̯wai/ → [ha̯wai]

3S.M-PL  
'they'

Figure 14 illustrates the utterances presented in examples (26) and (27).

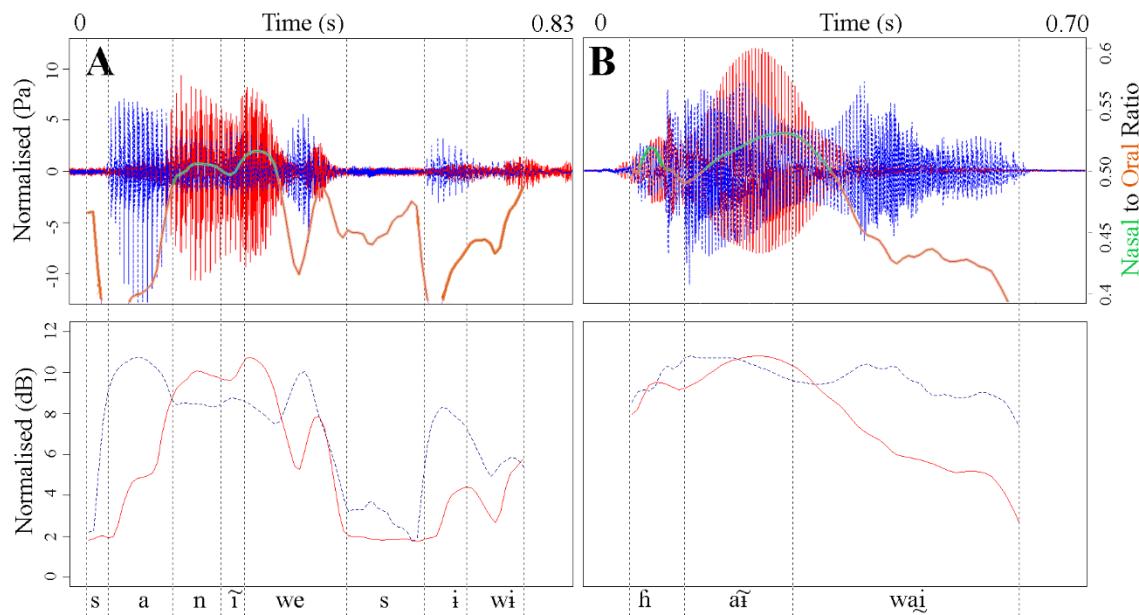


Figure 14: The Siona words provided in (26) and (27). Image A, produced by Consultant #2, contains an example of the nasalizer [n] which spread to [i] before becoming blocked by the diachronic word boundary. Image B, produced by Consultant #3, contains an example of the nasalizer [a̯i] which does not spread to the following segment [w] that would undergo nasalization if it were not grammaticalized.

Figure 14A reveals that the nasal to oral intensity ratio quickly decreases into the oral range directly after the nasalized [i] and does not regain substantial prominence throughout the remaining three syllables ([we.si.wi]). Figure 14B reveals a similar trend in the grammaticalized item in (27). Under “normal” conditions, we would expect [wai] to undergo nasalization; however, in this case the nasal-to-oral ratio intensity curve indicates a lack of nasality during the utterance of *hua'i*. The question remains how to interpret these nasal spread blocking elements synchronically. One possible analysis is that these suffixes form a new more independent domain and that these elements are not targets of nasal spread.

## 6 Nasality from a Tukanoan perspective

The Tukanoan family, to which Siona belongs, has played an important role in phonological theories of nasality and nasal harmony (Botma 2004; Piggott 1992; Piggott & Van der Hulst 1997; Walker 2000; 2011). The systems of nasal harmony that were found in many Tukanoan languages, and other South American indigenous languages, are often referred to as the Tukanoan pattern or type. One of the distinguishing features of this pattern is that many non-target segments are transparent and they do not block nasal spreading (Botma 2004: 124; Piggott 1992: 45–61). In this section, we introduce the Tukanoan family, discuss the major variables that are found with respect to nasality in these languages, and we address variation within the family. Important variables to consider are: (i) the domain(s) in which nasality operates, (ii) the possible directions of nasal harmony, and (iii) the behavior of specific phonemes with respect to nasality (e.g., triggers, targets, transparent segments, & blockers).

The Tukanoan family consists of two branches: Eastern and Western. The Eastern languages are spoken in the Eastern Lowlands of Colombia and in North-East Brazil. This branch comprises an estimated 16 living languages (Chacon 2014: 276–282) and contains more speakers than the Western branch. Ecuadorian Siona is part of the Western branch, which is considered to contain four languages that are still spoken: Koreguaje, Siona, Sekoya, and Máihíki (Barnes 1999; Chacon 2014). However, since Siona and Sekoya are very closely related, one could consider them to form a language continuum. The name "Siona" is used to refer to two distinct varieties, one spoken in Colombia and another one spoken in Ecuador. The name Sekoya is used for both an Ecuadorian and a Peruvian variety that show differences as well. Since Ecuadorian Siona and Sekoya are spoken in geographic areas that are in very close proximity, these varieties show many similarities and are in some respects more similar than Colombian Siona and Ecuadorian Siona. This may be due to the fact that when the Sekoya settled in Ecuador the 1940's they intermarried with the Siona that were already living in the same area. The varieties then underwent a leveling process during which certain features transferred while others were maintained.

Nasal harmony is a common process in Eastern Tukanoan languages, whereas it is less prominent in the Western branch. Kaye (1971) was the first to describe nasality as a suprasegmental feature in a Tukanoan language (Desano). According to Barnes (1999: 211), nasality in Eastern Tukanoan languages is an autosegmental phenomenon that is directly linked to the morpheme. In these languages, all non-transparent oral segments have phonetically nasal counterparts when they occur in a [+NASAL] environment (Barnes 1991: 33).

In a more recent study of Desano, Silva (2012), building on Kaye's (1971) earlier work, describes nasal harmony as a word-level feature that spreads from roots to affixes (rightward spread). In the case of Barasana and Tatuyo, Gómez-Imbert (2003; 2004) also describes nasality as a morphemic phenomenon, and not as a feature of individual segments. In short, a feature that most Eastern Tukanoan languages seem to have in common is that nasality is a suprasegmental feature of the morpheme.

In these languages, nasal harmony is rightward spreading as evidenced by the fact that it begins in the root and that suffixes are also targeted. Example (28), from Barnes (1999: 212), illustrates rightward spreading through an underspecified ([ØNASAL]) syllable into the suffix -ja in Tuyuka.

- (28) Tuyuka (Barnes 1999: 212)  
 pō̃-ja [pō̃-jā]  
 open-IMP  
 ‘open (it)’

According to Barnes (1999: 211), some Eastern Tukanoan languages<sup>19</sup> (namely, Desano, and Siriano) also show a limited degree of leftward spreading, however this only affects a small number of morphemes. The general consensus from these analyses of Eastern Tukanoan languages is that spreading occurs at the domain of the word. Furthermore, morphemes are [+NASAL], [-NASAL], or [ØNASAL]; morphemes with the feature [+NASAL] spread nasality to the following morpheme(s) in the word, [-NASAL] morphemes are blocking morphemes for nasality, and [ØNASAL] morphemes become nasal following a nasal morpheme (Barnes 1996; Gómez-Imbert 2003: 174–177; 2004: 51; Stenzel 2007: 341). This is illustrated below with examples from Kotiria (Stenzel 2007).

- (29) Kotiria (Stenzel 2007: 343 & 345))
- a. [+NASAL] + [ØNASAL]  
   ~badu+ro [mānū̃rō]  
   husband+ANIM.S  
   ‘a husband’
  - b. [-NASAL] + [ØNASAL]  
   die+ro [diero]  
   dog+ANIM.S  
   ‘a dog’
  - c. [+NASAL] + [-NASAL] + [+NASAL]  
   ~basa+yaka+ida [māsājā<sup>h</sup>kãnā]  
   people+steal+NOM:PL  
   ‘kidnappers’

Example (29a) and (29c) show examples of initial [+NASAL] roots.<sup>20</sup> A following [ØNASAL] becomes nasal (29a), whereas a following [-NASAL] morpheme does not, though it does not preclude a following [+NASAL] morpheme from surfacing as nasal (29c). A [ØNASAL] morpheme remains oral after a [-NASAL] morpheme (29b).

Because nasality is a suprasegmental feature of the morpheme in Eastern Tukanoan languages, there are no inherently nasal segments; segments are either targets or transparent to nasal spread. Kaye (1971: 37) shows that all voiced consonants and vowels are targets for nasalization, whereas all voiceless stops and fricatives are transparent, as the first morpheme in (29c) shows for Kotiria. Additionally, in Barasana and Tatuyo, both consonants and vowels function as nasal targets when present in a nasal spread, with the exception of the voiceless stops /p, t, (c), k/, which are transparent (Gómez-Imbert 2003: 175; 2004: 51). Stenzel (2007: 341) provides a similar analysis for Kotiria except that the set of transparent segments is larger (/ph, th, kh, s, ʃ, p, t, k/). There is some degree of variation regarding which consonants may become nasalized in a spread, but most Eastern Tukanoan languages include /w, j, h, r/, if the segment is in morpheme-initial position (Barnes 1999: 212), which is in line with Walker’s (2000) hierarchy illustrated in Example (5).

<sup>19</sup> Also see Gomez-Imbert (2004: 64–65) for Barasana.

<sup>20</sup> We follow Stenzel’s (2007) representation of these nasal roots as [+NASAL].

It should be noted that not all Eastern Tukanoan languages have morphemic nasality. For example, in Kubeo, nasality is a feature of the syllable. Even though morphemes do not necessarily show nasal harmony, there are a limited number of morphemes that function as blockers of rightward nasal spread. Rightward spread operates at the domain of the word and can be blocked by these morphemes and various other segments. Leftward nasal spread can nasalize a previous syllable, though this has been analyzed as phonetic co-articulation. Moreover, Kubeo separates itself from the branch as it does not contain transparent segments and there is a clear division between [±VOICE], with [+VOICE] segments functioning as targets and [-VOICE] segments functioning as blockers (Chacon 2012). An interesting characteristic of other Eastern Tukanoan languages (except Kubeo) is the fact that they do not possess any blockers.

The Western Tukanoan languages, on the other hand, have been described as even more variable than the Eastern branch regarding nasality. Firstly, in analyses of Western Tukanoan languages, nasality seems to operate in numerous domains, e.g., the segment, syllable, morpheme, and word. Secondly, in contrast to Eastern Tukanoan languages, various Western languages are described as possessing nasal segments. According to Cook and Criswell (1993: 2), Koreguaje possesses 5 nasal consonants as phonemes, two voiceless <m, ñ> (/m, ñ/) and three voiced consonants <m, n, ñ> (/m, n, ñ/) (see Examples (30) & (31)). The voiced nasal segments are contrastive with the three oral consonants <p, r, j> (/p, r, dʒ/), illustrated in examples (30) & (31):

- (30) Koreguaje (Cook & Criswell 1993: 5–6)

- a. /máʔá/ ‘trail’
- b. /máwáʔi/ ‘little creature’
- c. /p̪amí/ ‘it’s not deep’

- (31) Koreguaje (Cook & Criswell 1993: 5–6)

- a. /ñámá/ ‘deer’
- b. /ñañúmi/ ‘drag’
- c. /jéamí/ ‘gab’

According to Cook and Criswell, there is a nasal-oral contrast, which appears in the first syllable of the root, except in syllables that begin with a nasal consonant, where the vowel is always nasalized (Cook & Criswell 1993: 7).

Cook & Criswell (1993: 7) do not take a clear stance on the phonemic status of the nasal vowels; instead, they provide two possible analyses: (i) they are inherently nasal segments or (ii) they are affected by autosegmental nasality (Cook & Criswell 1993: 7). Possible evidence for the first analysis is that the nasal quality of vowels following oral consonants does not seem to be predictable<sup>21</sup> from the few examples presented in (Cook & Criswell 1993):

- (32) Koreguaje (Cook & Criswell 1993: 8)

- a. /kʰáá/ ‘branches’
- b. /kʰaa/ ‘piece of clothing’

- (33) Koreguaje (Cook & Criswell 1993: 8)

- a. /séwí/ ‘beard’
- b. /s̪esé/ ‘peccary’

---

<sup>21</sup> All nasal vowels in the presented examples show a low tone and all oral vowels show a high tone. There are, however, no indications in Cook & Criswell (1993) that there is a relation between tone and nasality. Therefore, we take this to be merely coincidental.

- (34) Koreguaje (Cook & Criswell 1993: 8)
- a. /kó-í/ ‘dirt’
  - b. /kõsá/ ‘fruit sp.’

The second analysis that Cook and Criswell (1993: 7) propose may suggest that nasality does not just operate within a segmental domain, but also within the domain of the morpheme.

Cook and Criswell (1993: 8–9) show that there is both rightward and leftward spreading of nasality in Koreguaje, even though the latter is restricted to the plural suffix [-ã]. Rightward spreading events can extend until the end of the word if there are no blockers, whereas leftward spreading seems to be restricted to the syllable, showing that both the domain of the word and the syllable are relevant to nasality in Koreguaje.

Various segments show a distinct type of behavior with respect to nasality in Koreguaje. Firstly, the language possesses inherently nasal segments <m, ñ, m, n, ñ> (/m, n, m, n, n/) and possibly /i, ï, û, ë, õ, ã/, that could be triggers of nasal spread depending on the analysis. Furthermore, Cook & Criswell (1993: 8) clearly state that the vowels (/i, i, u, e, o, a/) and the alveopalatal consonant /j/ (/dʒ/) are targets of nasal spread. However, the authors do not describe whether the consonants /w, h/ are targets or transparent to nasal spread. These consonants are transcribed as oral in the presented examples. Cook & Criswell (1993: 8) describe all stops and /s, r/ (/s, r/) as blockers of nasal spread.

Colombian Siona is also described by Wheeler (1987) as containing phonemic nasal segments, albeit with a more reduced set of nasal consonants. According to this author, the language has contrastive oral and nasal phonemes (/m-b/ & /n-r/), yet voiceless nasals are not documented in the language (Wheeler 1987: 88). Additionally, the author also analyses the nasal vowels as phonemes (Wheeler 1987: 84).

Colombian Siona, like Koreguaje, shows rightward and leftward spreading of nasality. Rightward spreading takes place within the domain of the word if there are no blocking segments (see Example (35)). Leftward spreading seems to take place within the domain of the syllable (see Example (36)); Wheeler (1987: 93) states that the suffixation of the plural marker [-ã] causes nasal spread to the previous vowel. The examples below illustrate spreading events in the language:

- (35) Colombian Siona (Wheeler 1987: 93)<sup>22</sup>
- kã- + -i + -ha? + -ye → kã-í-hã?-yẽ [k<sup>h</sup>ãíhã?ñẽ]  
 ‘sleep’ ‘middle voice’ ‘potential aspect’ ‘present participle’  
 ‘The nap they (s)he is going to take.’
- (36) Colombian Siona (Wheeler 1987: 93)
- ?ó-bo + -ã → ó-bõ-ã [?óbõã]  
 ‘plantain’ ‘plural’  
 ‘plantains’

Because of the nature of these spreading events, it seems that nasality operates within the domain of the segment, syllable, and word in Colombian Siona. There is no indication from Wheeler’s description that the domain of the morpheme plays a role in nasal harmony in the language.

Segments again show a varied type of the behavior in Colombian Siona. The nasal phonemes /m, n, ñ, ï, û, ë, õ, ã/ seem to function as triggers of nasal spread, which is transmitted through the consonants /w, j, h, h<sup>w</sup>, ?/ to the following vowel(s). It seems that of the consonants /w, j/ are targets of nasal spread to the vowels as well, and /h, h<sup>w</sup>, ?/ are transparent to nasal spread (Wheeler 1987: 93). All other consonants, including the stops, the fricative /s/, and the affricate /ʃ/ function as blockers.

Sekoya is also described as having phonemic nasal segments, but with an even more limited set than Koreguaje and Colombian Siona. The main difference between Colombian Siona and the Sekoya varieties is that [n] is not a phoneme, but rather an allophone of /d/ in a nasal environment (see Johnson & Levinsohn

<sup>22</sup> The glossing conventions are kept as well as possible from the original source.

1990: 15; Vallejos 2013: 77). Vallejos (2013: 73) describes the nasal vowels as phonemic, with /m, ñ, ï, û, ë, ð, ã/ acting as phonemes. Rightward nasal spread is described for both the Ecuadorian (Johnson & Levinsohn 1990: 21) and the Peruvian variety (Vallejos 2013: 79–80). Johnson and Levinsohn (1990) also provide examples of leftward nasal spread in the case of the plural suffix [-ã]. Once again, rightward spread seems to operate at the domain of the word and leftward spread at the domain of the syllable. There is no clear indication from the above-mentioned descriptions that nasality also operates with the domain of the morpheme.

Sekoya segments seem to show the following behavior when it comes to nasality: the nasal phonemes /m, ñ, ï, û, ë, ð, ã/ function as triggers, the voiced stop /d/ and the vocoids /i, i, u, e, o, a, w, j/ function as targets, the glottal consonants /h, ?/ are transparent to nasality, and all other consonants are blockers /p, t, k, k<sup>w</sup>, ts/.

According to the analysis by Sylak-Glassman et al. (2014), nasality does not operate within the segmental domain in Máíh̄iki. These authors describe nasality in Máíh̄iki as morpheme-internal nasal harmony, which does not cross morpheme boundaries. In example (37), the nasality of /ñ/ in the root *hñi-* ‘to be sick’ does not spread to /i/ in the subject and tense marking suffix -dʒi.

- (37) Máíh̄iki (Sylak-Glassman et al. 2014: 4)

/hñi-dʒi/  
be.sick-N3S.PRS<sup>23</sup>  
'I am sick.'

Although Máíh̄iki does not spread nasality over a morpheme boundary, the spreading events within a morpheme seem to be rightward (Sylak-Glassman et al. 2014). The language also seems to show limited leftward spreading restricted to the plural morpheme -ã, as described for the other Western Tukanoan languages (Farmer, Pers. Comm.). This analysis suggests that nasality operates within the domain of the syllable (leftward spreading) and that of the morpheme. It does not operate within the domain of the segment or the word.

Since nasality is triggered on a morphemic level, there are no segmental triggers of nasal spread in Máíh̄iki, according to the analysis by Sylak-Glassman et al. (2014). The targets for nasal harmony are the consonants /b, d, dʒ/ and all the vowels /i, ñ, u, e, o, a/. Nasality can spread through a fricative /h/, however, it is not stated whether this phoneme is transparent or a target of nasal harmony. The other consonants /p, t, k, k<sup>w</sup>, g, g<sup>w</sup>, s/ function as blockers.

The differences described here among the Western Tukanoan languages seem to be partially due to differences in analyses by different authors. However, some of the differences such as the lack of leftward spread of nasality throughout the word in Máíh̄iki, and the allomorphic status of [n] as the nasal counterpart of /d/ in Sekoya seem to be clear differences in the nasal systems of the languages. In the discussion (§7), we will compare the Tukanoan systems with the Siona system that we described in §5.

## 7 Discussion

The present study provides a description of the nasal system in Ecuadorian Siona using a new acoustic method developed specifically for collecting data in the field. The Earbuds Method provided a cost-effective method that was well received by the community members in Sototsiaya. Through this method, we were able to infer velum gestures in the data through two levels of analysis, (i) visual observations of the differences in amplitude (Pa) between the nasal and oral channels, and (ii) quantifiable observations through a nasal to oral intensity (dB) ratio. Timing gestures observable in both analyses revealed well-known properties of nasality (see e.g., Cohn 1990) such as anticipatory and perseverative nasalization, in addition

<sup>23</sup> The glosses were added here for clarification.

to the variability in intensity and amplitude of sound exiting the nasal cavity caused by varying degrees of velum aperture. Furthermore, the oral and nasal qualities of nasal vowels were apparent in the nearly equal levels of amplitudes during the production of segments. Blockers were another identifiable feature as amplitude and intensity from the nasal tract either dropped off completely (e.g., during the closure phase of stop consonants) or tapered off (e.g., during fricatives) and did not reappear in the following segments. The identification of numerous blockers confirms previous impressionistic findings (see e.g., Bruil 2014; Wheeler 1987) that Siona differs from most Eastern Tukanoan languages (e.g., Kotiria, Barasana, Tatuyo) that have been described as having transparent stop consonants (Gómez-Imbert 2004 for Barasana and Tatuyo; Stenzel 2007 for Kotiria), with Kubeo being the exception with all voiceless segments functioning as blockers (Chacon 2012). The results confirm the description of the nasal harmony pattern in the literature, and therefore suggest that the Earbuds Method can be fruitfully applied to other nasalization phenomena.

Because temporal information of velum gestures was observable in the data, analyzing nasal spreading acoustically was also possible. Findings revealed that speakers of Siona, like most speakers of Tukanoan languages, predominantly make use of rightward spreading in nearly every nasal event. However, compared to Eastern Tukanoan languages, Siona has fewer targets, restricted to vocoids and /h/, and fewer transparent segments, arguably only the glottal stop. Contrarily, Siona has a number of blocker segments that interrupt nasal spread; these include /p, t, k, kʷ, p̪, t̪, k̪, kʷ̪, ſ, s, ſ̪/. Siona also shows syllable-delimited leftward spreading with vocoids resulting in oral-nasal contrasts at the level of the syllable e.g., /wa/ ([wa]) vs. /wā/ ([wā]); this is also observed with plural suffix [-ã] triggering leftward nasal spread to preceding vocoids within the syllable. An interesting finding from the acoustic measurements is that leftward spreading is restricted to segments with high sonority (vocoids) leaving /h/ simply as a target in rightward spreading events.

The contrastive distribution of /m/ and /n/ in opposition to the laryngealized /p̪/ and /t̪/, in addition to their role as nasalizers, was also confirmed with the acoustic measurements. Moreover, there is no trigger that turns /p̪/ and /t̪/ nasal, providing additional evidence to the argument that they should be analyzed as independent phonemes. Due to the fact that /m/ and /n/ are not the allophonic nasal counterparts of the oral laryngealized (creaky) stops, nasality cannot be generalized as a morphemic feature in Ecuadorian Siona, but rather nasalization needs to be analyzed as a feature that is instigated by a single nasal segment. Because of the existence of phonemic nasality, the phoneme inventory of Siona possesses more nasal phonemes than in Eastern Tukanoan, namely 8 (/m/, /n/, /í/, /í̄/, /ú/, /é/, /ó/, and /á/), which either have none or a reduced set of nasal phonemes. Eastern Tukanoan languages and Máihíkì are analyzed as having no nasal phonemes, because nasality is a morphemic feature (Barnes 1996; 1999; Chacon 2012; 2016; Gómez-Imbert 2004; Stenzel 2007; Sylak-Glassman et al. 2014; *intra alia*). The phonemic inventory of Sekoya is analyzed as containing nasal segments albeit fewer than in Ecuadorian Siona. For example, the reduced number of nasal phonemes is due to the fact that [n] is an allophone of /d/ in this language (Johnson & Levinson 1990; Vallejos 2013). Wheeler's (1987) analysis of nasal segments in Colombian Siona is similar to our findings for Ecuadorian Siona's phoneme inventory (/m/, /n/, /í/, /í̄/, /ú/, /é/, /ó/, and /á/). In the case of Koreguaje, Cook and Crisswell (1993) do not make a strong claim about the number of nasal segments in its phoneme inventory. However, there is a larger set of nasal consonants, because the inventory includes voiceless nasals. As for the nasal vowels, the authors do not take a stand on whether they form part of the phoneme inventory. An acoustic study of the Koreguaje nasal system would shed more light on the history of nasality in Tukanoan. A summary of the nasal properties of the different Eastern and Western Tukanoan languages including Ecuadorian Siona is summarized in Table 4.

Table 4: Domains, directions, and behaviors of nasality in Tukanoan including Ecuadorian Siona

Language	Branch	Domains				Direction		Segment behavior				Sources
		Seg	Syll	Morph	Word	Prog	Reg	Triggers	Targets	Trans	Blockers	
Barasana	Eastern			X	X	X	X	-	/i, i, u, e, o, a, b, d, g, w, j, r, h/	/p, t, c, k/	-	(Gómez- Imbert 2003; 2004)
Desano	Eastern			X	X	X	X	-	/i, i, u, e, o, a, b, d, g, w, j, r/	/p, t, k, s, h/	-	(Kaye 1971; Silva 2012)
Kotiria	Eastern			X	X	X		-	/i, i, u, e, o, a, b, d, g, w, j, r, h/	/p <sup>h</sup> , t <sup>h</sup> , k <sup>h</sup> , s, f, p, t, k/	-	(Stenzel 2007; 2013)
Tatuyo	Eastern			X	X	X		-	/i, i, u, e, o, a, b, d, g, w, j, r, h/	/p, t, k/	-	(Gómez- Imbert 2004)
Kubeo	Eastern		X	±	X	X	X <sup>l</sup>	-	/i, i, u, e, o, a, w, b, d, r/	-	/h, p, t, k, s, f/	(Chacon 2012)
Colombian Siona	Western	X	X?		X	X	X	/m, n, ñ, ĩ, ũ, ē, õ, ã/	/i, i, u, e, o, a, w, j/	/h, h <sup>w</sup> , ?/	/(p), t, k, k <sup>w</sup> , p, t, (k, k <sup>w</sup> ) tʃ, s, (s)/	(Wheeler 1987)
Koreguaje	Western	X	X	?†	X	X	X	<m, ñ, m, n, ñ, (ĩ, ũ, ē, õ, ã)>‡	/i, i, u, e, o, a, w?, j, h?§	-	/p <sup>h</sup> , t <sup>h</sup> , t <sup>hw</sup> , k <sup>h</sup> , k <sup>hw</sup> , p, t, k, k <sup>w</sup> , ?, s, r/	(Cook & Criswell 1993)
Máihikí	Western		(X)	X		X	X*	-	/b, d, dʒ, i, i, u, e, o, a/	/h/?	/p, t, k, k <sup>w</sup> , g, g <sup>w</sup> , s/	(Sylak- Glassman, Farmer, & Michael 2014)
Sekoya	Western	X	X		X	X	X	/m, n, ñ, ĩ, ũ, ē, õ, ã/	/d, i, i, u, e, o, a, w, j/	/h, ?/	/p, t, k, k <sup>w</sup> , ts/	(Johnson & Levinsohn 1990; Botma 2004; Vallejos 2013)
Siona	Western	X	X	X	X	X	X	/m, n, ñ, ĩ, ũ, ē, õ, ã/	/i, i, u, e, o, a, w, j, h/ ¶	?/	/(p), t, k, k <sup>w</sup> , p, t, (k, k <sup>w</sup> ) f, s, (s)/	This study

\*(Stephanie Farmer, Pers. Comm.)

†Cook &amp; Criswell (1993: 7) mention the possibility of Koreguaje containing an autosegmental feature of nasality. If this would be an adequate analysis for the language, it is likely that this feature operates within the domain of the morpheme.

‡Cook &amp; Criswell (1993: 7) state that nasal vowels could either be analyzed as phonemes or as a target of autosegmental nasality.

§Cook &amp; Criswell (1993: 8) do not describe whether the consonants /w, h/ are targets or are transparent to nasal spread. These consonants are transcribed as oral in the presented examples.

<sup>1</sup>Not part of the phonology, but a phonetic aspect of anticipatory nasalization

<sup>2</sup>/h/ is only a target in rightward spreading and no evidence from our analysis suggests that it functions as a target in leftward spreading events. However, in rare cases it functions as a transparent segment in rightward spread.

The observations about nasal segments being part of the Siona phoneme inventory apply to the synchronic account of the system. It is possible that historically nasal phonemes did not exist in Proto-Tukanoan. A possible argument may come from the structure of Siona roots. Like in Máíhñki, some root structures are not attested in Siona (e.g.,  $\tilde{V}+r/\beta$ ). This may suggest that root-internally, the phonemes /p/ and /t/ become /m/ and /n/ following a nasal vowel. Siona also exhibits features of morphemic nasality. Similar to Eastern Tukanoan languages, Siona contains suffixes that are inherently nasal ([+NASAL]), suffixes are inherently oral ([‐NASAL]), and suffixes that can either be nasal or oral ([ØNASAL]). One issue that needs to be explained is the contrast of /p/ and /t/ with /m/ and /n/ in word-initial positions. Ecuadorian Siona /p/ and /t/ are cognate with the voiced stops /b/ and /d/ in Eastern Tukanoan languages and these voiced stops are the oral counterparts of /m/ and /n/ in oral morphemes in these languages. Therefore, it would be the laryngealized consonants /p/ and /t/ in Siona that would be the best candidates for being oral counterparts of the nasal stops /m/ and /n/. This contrast in Ecuadorian Siona should be considered a topic of future research.

## Abbreviations

2	second person
3	third person
ANIM	animate
ASS	assertive
CLS	classifier
CMPL	completive
DEP	dependent
DEM	demonstrative
FUT	future
GEN	general
IMP	imperative
M	masculine
MED	medial
N	non
OBJ	object
PL	plural
PRS	present
PST	past
REP	repetitive
S	singular
SBJ	subject
SS	same subject

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