An acoustic description of Mixean Basque

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This paper presents an acoustic analysis of Mixean Low Navarrese, an endangered variety of Basque. The manuscript includes an overview of all previous acoustic studies performed on different Basque varieties, in order to synthesize the sparse acoustic descriptions of the language that are available. This synthesis serves as a basis for the acoustic analysis performed in the current study, in which we replicate the various acoustic descriptions given in previous studies in a single, cohesive general acoustic description of Mixean Basque. The analyses include formant and duration measurements for the six-vowel system, voice onset time measurements for the three-way stop system, spectral center of gravity for the sibilants, and number of lingual contacts in the alveolar rhotic tap and trill. Important findings include: a centralized realization ([ʉ]) of the high-front rounded vowel usually described as /y/; a data-driven confirmation of the three-way laryngeal opposition in the stop system; evidence in support of an alveolo-palatal to apical sibilant merger; and the discovery of a possible incipient merger of rhotics. These results show how using experimental acoustic methods to study under-represented linguistic varieties can result in revelations of sound patterns otherwise undescribed in more commonly studied varieties.

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I. INTRODUCTION

Basque is a well-known language in terms of general linguistic description. A number of reference grammars can be consulted for particular details on its syntax or its phonology (especially Hualde and Ortiz de Urbina, 2003). Nevertheless, there are no general acoustic descriptions of the language, simply a limited number of papers that include acoustic characterizations of specific segments as produced in particular varieties of Basque. In this paper, we present a general acoustic description of an endangered variety of Basque, namely Mixean Low Navarrese—henceforth, "Mixean Basque" or "Mixean". Most of the work on the linguistic description of this variety has been carried out by the Basque dialectologist Iñaki Camino, who started performing fieldwork in the Mixe region in the early 1980s. His work involves general phonological, morpho-syntactic, and lexical descriptions (Camino, 2016). Another scholar who has focused on this dialect, but mainly on its morpho-syntax, is Martin Haase (1992). Given that the acoustics of Mixean Basque have never been discussed in previous work, we will compare our results with the acoustical description of each group of segments as described in different varieties of the language, insofar as they can be found in the literature.

A. General background

The region of Mixe (*Amiküze* in Mixean Basque) is geographically situated in the South-West of France, in the Pyrénées-Atlantiques department. Within the Basque Country, it is located on the northern part of the historical province of Low Navarre or *Nafarroa Beherea*.

The population of Mixe was 7856 as of 2015 (Insee, 2019), although the number of speakers of Basque in the region is much lower (Camino, 2016). The Mixe region is formed by 32 towns, the main city being Donapaleu (*Dnaplü* in Mixean Basque and *Saint-Palais* in French), with a population of 1842 in 2016 (Insee, 2019). The variety of Basque spoken in the region, Mixean Basque or *amiküzera*, is usually classified as part of the Low Navarrese dialect (Michelena, 2011) or as a transition variety (Zuazo, 2008). Nevertheless, Mixean Basque has more in common, phonologically, with the neighboring Zuberoan dialect. See Figure 1 for a dialectal map of the Basque varieties, where the region of Mixe is marked in waved texture in the North-East.

Mixean Basque has historically been in contact with Bearnese Gascon to the North (Mixe being South of the region of Béarn) and Zuberoan Basque to the East. Due to an increasing French influence at all the levels of the society, the number of speakers of Basque or Gascon has steadily decreased in the region during the last century (Camino, 2016, p. 48-49). Although no study regarding the current language use in Mixe has been performed recently, Camino (2016, p. 51) describes the language as being on its way to disappearing, with children currently raised and schooled in French. According to a 2016 study by the association *Zabalik* (Camino, 2016, p. 55), only 9% of children (75 individuals) are currently schooled in a Basque-speaking model.

B. Mixean phonology

The phonemic inventory of Mixean Basque includes, at a minimum, 30 contrastive consonants—nine stops /p, t, c, k, pʰ, tʰ, cʰ, kʰ, b, d, ɟ, g/, 10 sibilants /s̺, s̻, ʃ, t̻s̻, t̺s̺,

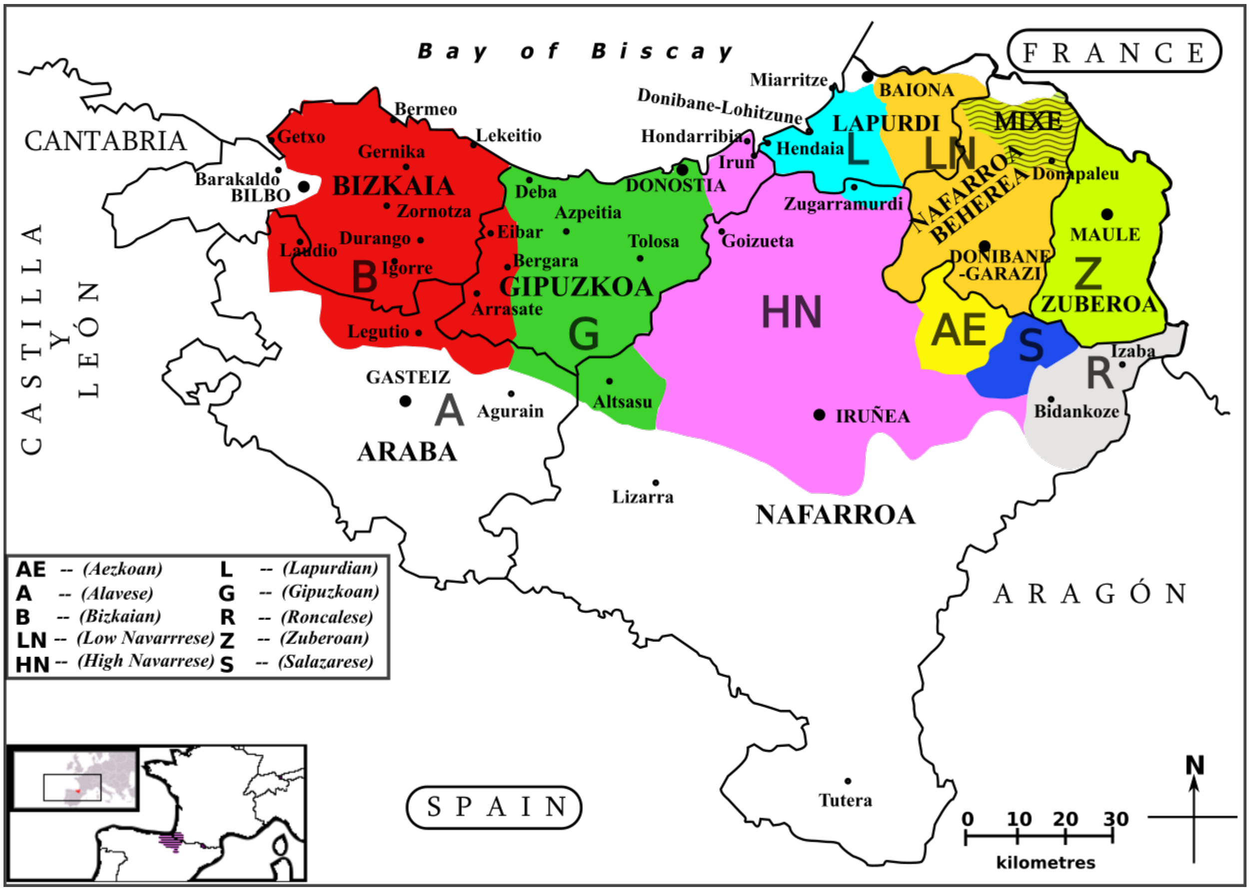


FIG. 1. (color online) Historical map of the Basque dialects adapted from Egurtzegi (2014). Mixe, the region where the variety researched in the current study is spoken, is highlighted in the North-East portion of the map with waved texture.

tʃ, z̺, z̻, ʒ, dz̻/, nine sonorants /m, n, ɲ, l, ʎ, ɾ, r, j, w/, two laryngeals /h, h̃/ (which are sonorant-like except word-initially)—and six contrastive vowels /a, e, o, i, y, u/, although not all segments are equally frequent. In addition, some non-nativized French loanwords are produced with /ʁ/, /æ/, /œ/, or nasalized vowels (phonemic segments that are present in French), although these are rare and generally not considered part of the Mixean Basque inventory. Excluding recent loanwords, there are no phonologically nasalized vowels in Mixean Basque (Camino, 2016, p. 200), but coarticulatory vowel nasalization can be found in contact to any of the nasal segments /m, n, ɲ, h̃/. Figure 2 shows the segmental inventory of the Mixean variety.

		labial		apical		laminal	predorsal		postdorsal	laryngeal
		bilabial	labio-dental	apico-dental	apico-alveolar	alveolar	palato-alveolar	palatal		
stop	voiceless	p		t				c	k	
	aspirated	pʰ		tʰ				cʰ	kʰ	
	voiced	b		d				ɟ	g	
Fricative	voiceless		f		s̺	s̻	ʃ			h/ɦ
	voiced				z̺	z̻	ʒ			
affricate	voiceless				ts̺	ts̻	ʧ			
	voiced				dz̺					
nasal		m			n			ɲ		
lateral					l			ʎ		
tap					ɾ					
trill					r					
glides								j	w	

	front	central	back
high	i y		u
mid	e		o
low		a	

FIG. 2. Phonemic inventory of Mixean Basque adapted from Hualde (2003) and Egurtzegi (2018b).

Some segments are only contrastive in particular phonological environments. Laryngeals and aspirated stops can only be found in the onset of the first two syllables of the word; stops are absent from word-medial codas and their laryngeal configuration is neutralized (to the plain voiceless series) in word-final position. Rhotics only contrast intervocallically; they are absent from word-initial position and they neutralize in tautosyllabic obstruent-rhotic onset clusters and in coda position to a segment that is not clearly described in the literature on this or any close variety. In his general description of Basque, Hualde (2003, p. 30) describes this neutralized rhotic as a trill realized with fewer vibrations. Regarding sibilants, /ʧ/ is the only affricate found word-initially, and voiced sibilants are mostly present in loanwords and compound boundaries such as *deuse* /deuz̺e/ ‘nothing (at all)’ (*deus* ‘nothing’ + *ere* ‘as well'). Sibilants preceding a voiced obstruent are also voiced. The sonorants /m, ɲ, ʎ/ do not occur word-finally. See Hualde (2003) for a description of the phonotactic restrictions of most Basque dialects.

The Mixean variety of Low Navarrese Basque shows a more complex phonemic inventory than general Low Navarrese or most other varieties of Basque. The only variety of Basque that has a more complex inventory is Zuberoan, which has a phonemic inventory similar to that of Mixean Basque but also includes four contrastive nasalized vowels (Egurtzegi, 2015). The most notable differences between Mixean and Zuberoan Basque and the other Basque varieties are the set of aspirated stops /p^h, t^h, c^h, k^h/, the nasalized laryngeal /h̃/, and the rounded high front vowel /y/. All other Basque varieties only have five vowels /a, e, o, i, u/, two sets of stops (voiced and voiceless unaspirated), and one (/h/) or no laryngeal approximants. Aspiration—both as a phonological segment (Egurtzegi, 2018b) and as a feature of a two-way stop distinction (Egurtzegi, 2018a)—was arguably part of an earlier, common stage of the language. However, contrastive aspiration is limited to the Easternmost varieties today, and it has been reported to show recession even in the dialects where it is most present, namely Zuberoan and Mixean. Although both Zuberoan and Mixean have been reported to have a front rounded vowel, Mixean /y/ has been auditorily described as different from Zuberoan /y/, and closer to /ø/, especially in pre-pausal position (Haase, 1992, p. 29). Another difference between Mixean and Zuberoan is that Zuberoan lost the tap in the 19$^{\text{th}}$ century, while Mixean still preserves two rhotics intervocalically.

II. PREVIOUS ACOUSTIC DESCRIPTIONS

Most acoustic descriptions of particular varieties of the Basque language focus either on sibilants or on the vocalic inventory. In addition to these, there are some studies by Gaminde and colleagues which focus on rhotics and a couple of studies on the stop system of Zuberoan Basque. We are not aware of any general acoustical study of any variety of the Basque language.

A. Previous findings: Vowels

Vowels are the most studied segments in the literature on Basque acoustics. The most general and complete work on the acoustics of vowel systems is Urrutia *et al.* (1995), which summarizes previous works and presents descriptions and formant charts of multiple dialects of the language. Among the varieties studied in this book we can find one that the authors call Eastern Low Navarrese (Urrutia *et al.*, 1995, p. 151-175), which includes three male speakers: one from Donibane Garazi (Cizean Low Navarrese), another from Donapaleu (Mixean Low Navarrese), and a third from the Salazar Valley (Salazarese dialect; see the map in Figure 1). This somewhat heterogeneous group is the closest reference to our data that can be found in the literature. Table I shows the aggregated formant values (F1 and F2), vowel durations, and respective standard deviations for the three participants.

There are a number of characteristics of the study which call into question the generalizability of these results to the current study. First, it only involved three speakers, each from very different sub-varieties, with no information on the sample size analyzed for each

TABLE I. F1 and F2 values (Hz), duration values (ms), and standard deviations in Eastern Low Navarrese (Urrutia *et al.*, 1995, p. 163-172).

Measure		Vowel				
		/i/	/e/	/a/	/o/	/u/
F1	Hz	347.9	503.5	730	520.6	382.8
	SD	*54.6*	*79.6*	*118.7*	*83.2*	*72*
F2	Hz	2277	1878.8	1469.1	1058.1	1035.8
	SD	*230.2*	*166.8*	*170.2*	*113.5*	*186.8*
Duration	ms	57	59.1	65	64.7	58.5
	SD	*18.5*	*19.9*	*15.8*	*27.6*	*17.5*

of them. The results are not presented by speaker, but only as aggregates, so we cannot extract the particular information about the Mixean informant. In addition, there is no information about /y/, a vowel which is contrastive in Mixean Low Navarrese, but which is not present in the varieties of the other two informants of the group (Cizean Low Navarrese and Salazarese); we could find no information on whether the instances of /y/ were discarded from the analysis or aggregated with the results for /u/, the segment to which it corresponds in the varieties of the two speakers who do not have /y/ in their inventory.

The only acoustic study of a variety of Basque that has a six-vowel inventory, namely Zuberoan Basque, is found in the same book (Urrutia *et al.*, 1995, p. 203-234). It presents the aggregate results of two informants of (Northern) Zuberoan Basque, with no sample size given. The results are shown in Table II. The authors specify that [ø] is not a contrastive vowel (Urrutia *et al.*, 1995, p. 206), but an allophonic variant of /y/, but we could not find a phonological context for this realization in their work, and this proposal is not standard elsewhere (Haase, 1992 proposes this allophone in prepausal position for Mixean as opposed to Zuberoan). The study concludes that stress does not play a significant role in the acoustic realization of Zuberoan vowels (Urrutia *et al.*, 1995, p. 206).

TABLE II. F1 and F2 values (Hz), duration values (ms), and standard deviations in Zuberoan (Urrutia *et al.*, 1995, p. 217-230).

Measure		Vowel						
		/i/	/e/	/a/	/o/	/u/	/y/	/ø/
F1	Hz	352.8	508.5	820.8	504.8	390	378.9	416.4
	SD	*46.1*	*91.6*	*69*	*76.6*	*61.4*	*33.9*	*40.1*
F2	Hz	2441.5	2002	1448.5	1024.2	948.8	1812.2	1755.2
	SD	*213.6*	*186.7*	*132.6*	*168.8*	*155.7*	*132.7*	*192.8*
Duration	ms	68	59.1	71	76.7	82.06	80.8	78.5
	SD	*21*	*19.9*	*22*	*17.9*	*23.4*	*21.5*	*18*

A study with a large number of speakers of a variety that is geographically close to the Mixe region is the PhD thesis of Pagola (1992), who acoustically analyzed the vowels of 18 speakers of (Northern) High Navarrese from Baztan, Bortziri, and Ultzama, as well as a speaker of Lapurdian from a neighboring town (Zugarramurdi). The aggregated results are shown in Table III. This study involves many more speakers that the studies mentioned previously, which improves the generalizability of the results as a basis for comparison with the current study. However, notwithstanding its geographic proximity to the Mixe region, the dialect studied in Pagola (1992) is somewhat limited in its relevance for the current study on Mixean Basque, given that: (1) Northern High Navarrese only has five vowels (rather than six, as in Mixean Basque), and (2) it was historically in contact with Navarrese and Castilian Spanish (rather than Gascon and French, as for Mixean Basque).

TABLE III. F1 and F2 values (Hz), duration values (ms), and standard deviations in (Northern) High Navarrese (Pagola, 1992, p. 97).

Measure	Vowel				
	/i/	/e/	/a/	/o/	/u/
F1 (Hz)	318.84	443.65	635.94	472.19	338.23
F2 (Hz)	2147.59	2009.61	1443.85	924.94	803.03
Duration (ms)	67.14	67.88	85.38	71.81	73.59

A nearly-exhaustive list of acoustic studies of Basque vowels would also include Salaburu (1984) with five speakers from Baztan (High Navarrese); Hualde *et al.* (2010) with two speakers from Goizueta (High Navarrese); Etxebarria Ayesta (1991, p. 48) with one speaker from Zeberio (Bizkaian); Gaminde (1992, 1995), with speakers from Urduliz and Gatika (Bizkaian); Etxebarria Arostegi (1995) also from Bizkaian; and Etxeberria (1990, 1991) with speakers of Zaldibia (Gipuzkoan). Etxebarria Arostegui (1991) and Iribar Ibabe and Túrrez Aguirrezabal (2001) do not specify the varieties under study.

B. Previous findings: Stops

Only a handful of studies can be found in the literature that analyze the acoustic realization of Basque stops. Two of these studies investigated Zuberoan Basque, which makes them relevant as a means of comparison for our study. Gaminde *et al.* (2002) analyzed the recordings of four male speakers of Zuberoan Basque (from the region of Pettarra), including a total of 302 analyzed tokens. The study is restricted to word-initial stops in a stressed syllable. The authors describe a three-way contrast involving prevoiced (negative voice onset time; VOT), plain voiceless (short-lag positive VOT) and voiceless aspirated (long-lag

VOT) stops. The aggregate mean results are shown in Table IV. Mounole (2004) performs a comparable study of the same dialect, also involving four male participants (from Larrain), including a total of 861 analyzed tokens. She analyzed word-initial voiceless stops and found a difference between plain voiceless and voiceless aspirated stops, with no significant differences due to stress (Mounole, 2004, p. 222).

TABLE IV. Stop VOT (ms) in Zuberoan (Gaminde *et al.*, 2002; Mounole, 2004).

Study	Stop consonant								
	/b/	/p/	/p^{h}/	/d/	/t/	/t^{h}/	/g/	/k/	/k^{h}/
Gaminde *et al.* (2002)	-102	20	61	-105	24	67	-101	27	83
Mounole (2004)		14	47		20	52		28	67

The other two studies on Basque stops found in the literature investigated intervocalic stop lenition. They demonstrate that (plain) voiceless stops show a tendency towards voicing and lenition in intervocalic position (Nadeu and Hualde, 2015), which is strongest for word-final voiceless stops when preceding a word-initial vowel (Hualde *et al.*, 2019).

C. Previous findings: Sibilants

There are six sibilants—represented orthographically as <s, z, x, ts, tz, tx>—that have traditionally been recognized as common to all Basque dialects. Most authors (Egurtzegi, 2013; Hualde, 2003; Michelena, 2011, inter alia) describe these segments as voiceless apico-alveolar (transcribed as /s̺, ts̺/), dorso- or lamino-alveolar (transcribed as /s̻, ts̻/), and post-alveolar (transcribed as /ʃ, ʧ/). A number of studies (Larrasquet, 1934; N'Diaye, 1970; Txillardegi, 1982) have described <s> as a retroflex sibilant (instead of apico-alveolar), usually referring to Eastern varieties of Basque, restricting the apico-alveolar realizations to varieties in contact with Spanish (N'Diaye, 1970, p. 15). Yárnoz (2002a,b) described the six sibilants in the Basque variety of Bortziri (Northern High Navarrese) as flat post-alveolar (transcribed by the author as /ṣ, tṣ/), denti-alveolar (/s̪, ts̪/), and palatalized post-alveolar (/ʂ̡, tʂ̡/) instead, although only Jurado Noriega (2011) followed this description for other varieties. In addition, some Eastern varieties have developed voiced sibilants that are mostly found in loanwords from Gascon and French and in *liaison* (Michelena, 2011, p. 230). In addition, some dialects (Bizkaian and Gipuzkoan in particular) have developed mergers, resulting in a reduction of the size of the sibilant inventory (see Muxika-Loitzate, 2017 and Beristain, 2018b for recent acoustic studies on sibilant merger in Bizkaian and Gipuzkoan). In Bizkaian and some neighboring varieties, this merger results in an apico-alveolar fricative and a lamino-alveolar affricate realization, whereas in Gipuzkoan it results in a lamino-alveolar fricative. In some varieties in contact with French, the apico-alveolar fricative merges with the palato-alveolar fricative instead (see Hualde, 2010 for a comprehensive discussion of sibilant mergers). Some authors have even concluded that the sibilant merger is a completed phonological process in Basque (Urrutia *et al.*, 1991, p. 331), but this assertion is only widely accepted for western dialects (Yárnoz, 2002b, p. 14).

As in the case of the vowels, the study that is geographically most relevant for comparison with our analysis is that by Urrutia *et al.* (1991). However, their study of Eastern Low Navarrese sibilants shares some of the shortcomings present in their aforementioned study on vowels (see Section II A) and, most importantly, they report the lower energy cut-off frequencies of the sibilants instead of their spectral center of gravity (CoG), reducing the comparability with more recent studies. The studies in Table V report the CoG of Basque sibilants, but they are not ideal for comparison with our study for various reasons: Iglesias *et al.* (2016) uses nonce words instead of lexical items, Gandarias *et al.* (2014) only includes three tokens for each sibilant, Beristain (2018b) and Muxika-Loitzate (2017) only analyze fricative sibilants (rather than both fricatives and affricates), Hualde (2010) and Iglesias *et al.* (2016) report results of a single speaker, and Gandarias *et al.* (2014) only provide complete CoG values from one speaker (female from Lekeitio) even though the speech of three speakers was analyzed. Unfortunately, all of these studies analyzed speakers from central and western dialects, while Mixean is one of the most eastern varieties of Basque. Note that Table V incorporates separate results from the three Basque-speaking groups (each including 6 female speakers, aged 21-27) in the recent, unpublished MA thesis by Beristain (2018b). Here, B stands for Bizkaian (Lemoa), where the apico-alveolar fricative merges with the lamino-alveolar in favor of the former; G stands for Gipuzkoan (Azpeitia), where the merger favors the latter; and HN for High Navarrese (Goizueta), where no merger is expected.

A nearly-exhaustive list of acoustic studies involving Basque sibilants would include Yárnoz (2002b), Hualde (2010), Jurado Noriega (2011), Gaminde *et al.* (2013), Gandarias *et al.* (2014), Iglesias *et al.* (2016), Muxika-Loitzate (2017), Beristain (2018a,b), Txillardegi (1982), Isasi Martínez *et al.* (2009), Urrutia *et al.* (1988), Urrutia *et al.* (1989), Urrutia *et al.* (1991), and Txillardegi (1982). Classic articulatory descriptions of Basque sibilants include Navarro Tomás (1923, 1925) and Alonso (1923).

TABLE V. Center of gravity (CoG; Hz) of Basque sibilants (Beristain, 2018b; Gandarias *et al.*, 2014; Hualde, 2010; Iglesias *et al.*, 2016; Muxika-Loitzate, 2017).

Study	Sibilant consonant								
	/s̻/	/ts̻/	/s̺/	/ts̺/	/ʃ/	/tʃ/	/d̻z/	/ʒ/	/dʒ/
Hualde (2010)	6645	7183	4173	4343	3531	3829			
Iglesias *et al.* (2016)	14,452	14,517	8081	6951	5966	7757			
Gandarias *et al.* (2014)		9469	6500		6588	10383	13136	8033	5394
Muxika-Loitzate (2017)	6610		6242		5770				
Beristain (2018b) B	5636		5925						
Beristain (2018b) G	7450		7160						
Beristain (2018b) HN	7914		5117						

D. Previous findings: Rhotics

Most, if not all of the previous studies on the realization of Basque rhotics have been performed by Gaminde and colleagues (Gaminde, 2006; Gaminde *et al.*, 2017, 2016). Gaminde *et al.* (2016) study the different realizations of intervocalic taps in 15 speakers (20–23 years old) of Bizkaian Basque. They measured duration, formants, and acoustic energy in a total of 330 tokens of read speech. They observed realizations of five allophones of the intervocalic tap in Basque—[ɾ, ɾ͡ɹ, ɹ͡ɹ, ɹ̝, r]—classified by whether the rhotic showed lingual contact and whether it showed fricative noise (partial frication, frication throughout the rhotic, or no frication at all). Gaminde *et al.* (2017) follow this work with a larger study on the realization of intervocalic trills, involving 155 young speakers (23–36 years old) from the whole Basque-speaking territory. Their results show that speakers of the peninsular varieties (central-western Basque dialects, in contact with Spanish) tend to use the trilled alveolar rhotic /r/, while speakers from the continental varieties (eastern Basque dialects, in contact with French) use voiced uvular rhotics /ʁ, ʀ/ instead. Interestingly, they report that all of the speakers of continental dialects in their study consistently used uvular rhotics. Their results are summarized in Table VI. Note that the subscript following the the transcription of the variants in Table VI represents the number of lingual contacts, if multiple.

TABLE VI. Allophones of the rhotic trill in Basque (Gaminde *et al.*, 2017). Numerical subscripts indicate the number of lingual contacts/taps.

Gaminde *et al.* (2017)	Rhotic allophone						
	[r]$_2$	[r]$_3$	[r]$_4$	[r͡ɹ]	[r͡ɹ̝]	[r̞]	[r̞]$_2$
Percentage	50	8.54	0.3	27.13	10.67	1.83	1.52
Total	164	28	1	89	35	6	5

E. Predictions for Mixean Basque

Based on the previous literature, we expect to find six vowel categories (including a front, rounded /y/) and three stop series (voiced, voiceless unaspirated, and voiceless aspirated), as reported for the closely related Zuberoan dialect. Regarding sibilants, we expect to find three places of articulation (apico-alveolar, lamino-alveolar, and alveolo-palatal, which might be slightly different between fricative and affricate counterparts), although some authors have reported the sibilant merger to be general. We expect to find an opposition of rhotics (tap and trill) in intervocalic context. We have no clear expectation of the realization of rhotics in neutralizing contexts (i.e. onset clusters and codas), although they might be articulated as trills with ≈ two lingual contacts, based on descriptions by (Hualde, 2003) and results observed in Gaminde *et al.* (2017).

III. METHODOLOGY

The data used for the acoustic analyses presented in the current study include audio recordings from Camino (2016) compiled after intensive fieldwork in the Mixe region during the last four decades. He recorded more than an hour of audio data from each of 15 speakers of Mixean Basque. All speakers lived in different villages from the Mixe region. From this data set, we have selected 10 audio recordings that were made within the past 15 years. The selected audio files were recorded in rural environments, with a portable minidisc recorder (SONY MZ-R30), at a sampling rate of 44.1 kHz. Recordings of speakers older than 85 years were excluded from the analysis to avoid age-related phonetic biases, and recordings made in the 1980s with a DAT recorder were excluded in order to obtain homogeneous data regarding the state of the language and the recording method used. The resulting corpus includes recordings from seven male speakers and three female speakers from 10 different villages (Donapaleu, Uhartehiri, Sorhapürü, Arrüeta, Martxüeta, Labetze, Amendüze, Gamue, Zohota and Arberatze) of the region of Mixe. The length of the recordings was 5.5 minutes on average, with a range of 3.5 minutes to 8.5 minutes ($SD = 1.7$). All audio recordings were force-aligned using the WebMAUS application (Kisler *et al.*, 2017) set to Basque (FR); the resulting Praat TextGrids were subsequently hand-corrected by either the first author, the second author, or a graduate student in phonetics. All acoustic analyses were performed in Praat (Boersma and Weenink, 2019) using custom-written functions created by the second author, following the protocols outlined below.

A. Methods: Vowels

We analyzed a total of 2221 vowel tokens, ranging between 112 and 370 tokens per speaker ($SD = 72.2$). Formant estimations were made using the Burg LPC method in Praat. The formant estimator was optimized for each speaker by manually adjusting the maximum formant parameter (five formant estimation) until the formant trajectories aligned consistently with visible formant bands in a broad-band spectrogram. Average F1 and F2 measurements were then obtained within the middle 10% of each vowel interval (i.e., a window equal to 10% of the vowel duration, centered on the vowel midpoint). Additionally, the duration of the entire vowel interval (in ms) was measured and logged.

The F1 and F2 measurements were then imported into R (R Core Team, 2019), where speaker-normalized values were computed using Lobanov normalization (i.e., z-score transformation). The resulting z-scores were then converted back to the Hz scale using the average standard deviation and grand mean of all 10 speakers. These normalized formant values maintain the interpretability of the Hz scale, while also retaining the speaker-specific normalized structure of the z-scores. Subsequently, the speaker-normalized F1 and F2 values were combined for each of the six vowels /i, e, a, o, u, y/ and vowel-specific z-scores were computed. Outliers were removed from each vowel category by excluding observations associated with vowel-specific F1 or F2 z-scores with absolute values greater than 3.

B. Methods: Stops

Only stops in utterance-initial position were included in the analysis, since stop lenition occurs intervocalically (Nadeu and Hualde, 2015), even across word boundaries (Hualde *et al.*, 2019). In this environment, the palatal stop series /ɟ, c, c^{h}/ was produced rarely in the data—/ɟ/ was produced twice by one speaker and one time each by three speakers; /c/ was produced four times by one speaker, three times by another speaker, and only once by a third speaker; /c^{h}/ was produced only one time by a single speaker. This stop series was therefore excluded from the final analysis. We analyzed a total of 755 stop consonant tokens, ranging between 45 and 124 tokens per speaker ($SD = 26.6$). Measurements of voice onset time (VOT) were made for the nine stop consonants /b, d, g, p, t, k, p^{h}, t^{h}, k^{h}/. VOT was first estimated automatically using AutoVOT (Keshet *et al.*, 2014) in Python (Python Software Foundation), trained on a subset of manually-annotated Praat TextGrids. The onsets and offsets of the estimated VOT segments were then manually verified by the second author and hand-corrected as needed. Before the final analysis, speaker-normalized z-scores were computed, and outliers were removed by excluding observations associated with z-scores with absolute values greater than 3.

C. Methods: Sibilants

We analyzed a total of 1689 sibilant consonant tokens, ranging between 109 and 237 tokens per speaker ($SD = 42.3$). Center of gravity (CoG) measurements for the sibilants /ʃ, ʧ, s̺, ts̺, s̻, ts̻, ʒ, z̺, z̻/ were obtained in Praat. CoG measurements were calculated from the absolute spectrum after band-pass filtering the audio (300 Hz to 19 kHz). For fricative consonants, average CoG measurements were obtained within the middle 10% of the consonant interval (i.e., the same analysis window used for F1 and F2 measurements of the vowels). For affricate consonants, the same 10% window was used for analysis; however, instead of centering the window on the midpoint of the consonant (i.e., 50% of the consonant interval) the window was centered on 75% of the consonant interval. This ensured that average CoG values were obtained in the fricative portion of the affricate and excluded the closure and/or release.

Although CoG measurements are not necessarily expected to vary between speakers due to the same factors that condition inter-speaker differences in formant frequencies of vowels (e.g., differences in vocal tract length between males and females), it is expected that some degree of inter-speaker variation in CoG may be observed due to differences in speaker morphology (e.g., height of the palate, formation of the teeth, etc.). Because of this, CoG values were Lobanov normalized before conversion back to Hz, in the same manner as previously described for F1/F2 values. Before the final analysis, outliers were removed by excluding observations associated with z-scores with absolute values greater than 3.

D. Methods: Rhotics

We analyzed a total of 482 rhotic tokens, ranging between 31 and 82 tokens per speaker ($SD = 14.6$); this included 296 /r/ tokens (speaker range 19–55, $SD = 10.5$) and 186 /ɾ/ tokens (speaker range 2–29, $SD = 8.1$). The number of lingual contacts made during the productions of /r/ and /ɾ/ was estimated programmatically in Praat according to the following method. The audio signal was first low-pass filtered at 2000 Hz, and an intensity/amplitude (dB) trajectory was generated from the filtered signal. Secondly, the intensity minima within the interval of each /r, ɾ/ token were identified, and the total number of minima within each interval was logged. We interpret each intensity minimum as a lingual contact, according to the understanding that any sort of intra-oral constriction will result in a loss of overall energy, due to the increased airflow impedance; a rapid constriction associated with a lingual tap is expected to result in a corresponding rapid loss of acoustic energy, thus producing an intensity minimum. Three environments were investigated: intervocalic /r, ɾ/ items, /r, ɾ/ items in onset clusters, and /r, ɾ/ items in coda position. As previously described in Section I B, rhotics only contrast intervocalically in Basque: they are neutralized in onset clusters as well as in coda position. Thus, separate analyses were carried out for /r/ and /ɾ/ in intervocalic position, but /r/ and /ɾ/ items were combined for the analyses of onset clusters and codas.

IV. RESULTS

A. Results: Vowels

The speaker-normalized F1/F2 acoustic vowel space is shown in Figure 3. The ellipses shown denote 50% of the data variation for each vowel category (i.e., data ellipses, not confidence interval ellipses). The colored vowel symbols denote the F1/F2 mean for each category; black bars connect the category means in order to help visualize the overall shape of the acoustic vowel space. With regard to F1 (i.e., acoustic vowel height), a three-way distinction can be observed: /i, y, u/ are realized as high vowels with similar F1 values,

/e, o/ are realized as mid vowels with similar F1 values, and /a/ is realized as a low vowel. However, it should be noted that the F1 distinction between the high vowels /i, y, u/ and the mid vowels /e, o/ is not as great as the F1 distinction between the mid vowels /e, o/ and the low vowel /a/. With regard to F2 (i.e., acoustic vowel anteriority/posteriority), the results are somewhat more varied. Among the three high vowels, there is a clear three-way distinction in which /i/ and /u/ are realized as front and back vowels, respectively, while /y/ is realized as a central (rather than front) vowel. These results suggest that /y/ would more appropriately be characterized as [ʉ] in this variety. The mid-vowels /e, o/ display a clear front-back distinction (although /e/ is much more retracted in comparison to /i/), while the low vowel /a/ is realized as a central vowel along the F2 dimension. These results suggest that the Mixean Basque vowel system is characterized by two front vowels (/i/ and /e/), two central vowels (/y/∼[ʉ] and /a/), and two back vowels (/u/ and /o/).

The average formant values for the six vowel categories are given in Table VII, along with findings from previous literature. A graphical representation of these values is shown in Figure 4. Overall, based on the findings from the current study and values reported in previous literature, the vowel space in Mixean Basque is more contracted and centralized compared to the Eastern Low Navarrese, Zuberoan, and High Navarrese varieties. Notable exceptions can be observed for /e/ and /o/, which have similar formant values to /e/ and /o/ of Eastern Low Navarrese, as well as /a/, which is slightly lower (i.e., higher F1 value) than High Navarrese.

Average vowel durations (ms) from the current and previous studies are given in Table VIII. With regard to /i/, Mixean Basque has the longest average duration (81 ms) among the

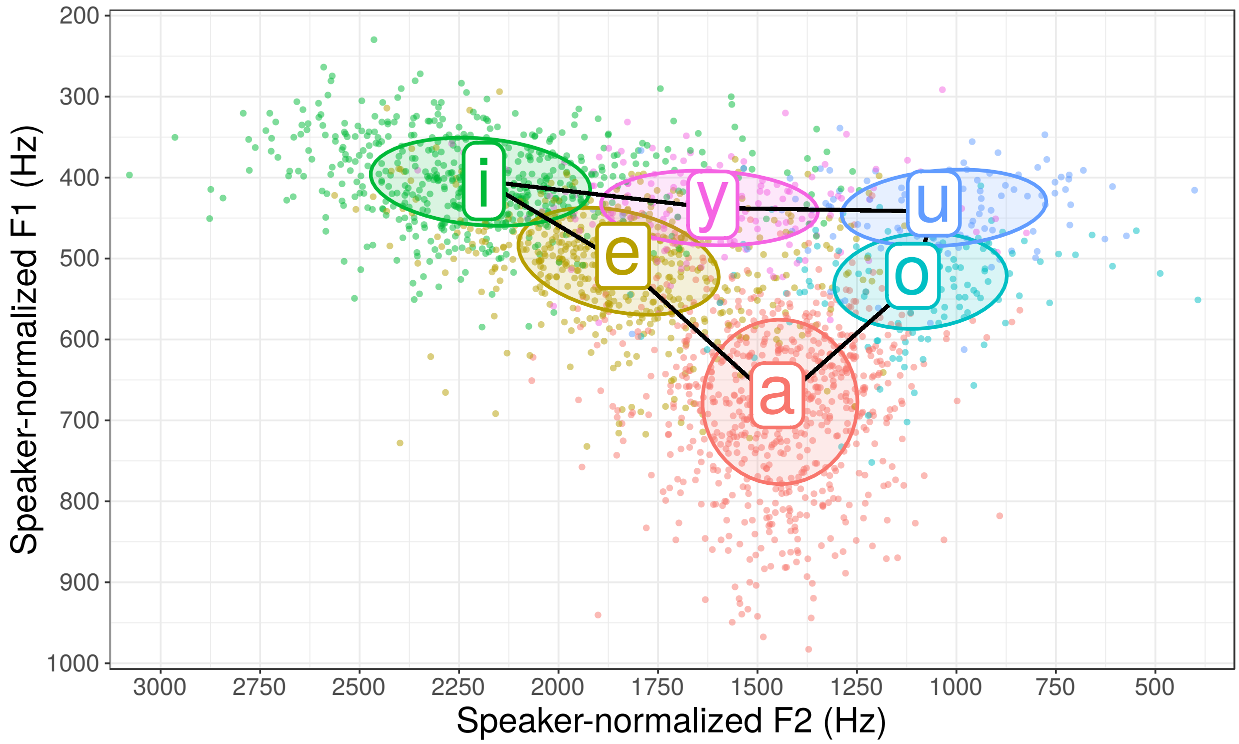


FIG. 3. (color online) Acoustic vowel space of speaker-normalized F1/F2 values (Hz) for Mixean Basque. Ellipses represent coverage of 50% of the data in each vowel category.

four varieties. Similar results can be observed for /e/, although the durations for Mixean (76 ms) and High Navarrese (68 ms) are more similar than for /i/. With regard to /a/, Mixean again displays the longest duration among the four varieties, although the average duration (88 ms) is fairly similar to the duration of /a/ in High Navarrese (85 ms). The vowel /o/ exhibits the longest duration in Mixean (98 ms), which is substantially longer than any of the other three varieties, where /o/ ranges from 65–77 ms. This suggests that while /o/ is the most centralized in the formant vowel space among the four varieties, it is perhaps realized as more tense than in the other three varieties. With regard to both /u/ and /y/, the duration values are similar to those observed in the Zuberoan variety.

TABLE VII. Vowel formant summary from Urrutia *et al.* (1995), Pagola (1992), and the current study.

Variety	Vowel													
	/i/		/e/		/a/		/o/		/u/		/y/		/ø/	
	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2
East. Low Navarrese (Urrutia *et al.*, 1995)	348	2277	504	1879	730	1469	521	1058	383	1036				
Zuberoan (Urrutia *et al.*, 1995)	353	2442	509	2002	821	1449	505	1024	390	949	379	1812	416	1755
High Navarrese (Pagola, 1992)	319	2148	444	2010	636	1444	472	925	338	803				
Mixean	404	2170	507	1838	679	1450	531	1110	442	1057	438	1612		

TABLE VIII. Vowel duration (ms) summary from Urrutia *et al.* (1995), Pagola (1992), and the current study.

Variety	Vowel						
	/i/	/e/	/a/	/o/	/u/	/y/	/ø/
East. Low Navarrese (Urrutia *et al.*, 1995)	57	59	65	65	59		
Zuberoan (Urrutia *et al.*, 1995)	68	59	71	77	82	81	79
High Navarrese (Pagola, 1992)	67	68	85	72	74		
Mixean	81	76	88	98	85	79	

B. Results: Stops

Voice onset time (VOT) values for voiced stops /b, d, g/, unaspirated stops /p, t, k/, and aspirated stops /p^h, t^h, k^h/ are displayed in box plots in Figure 5. In this figure and

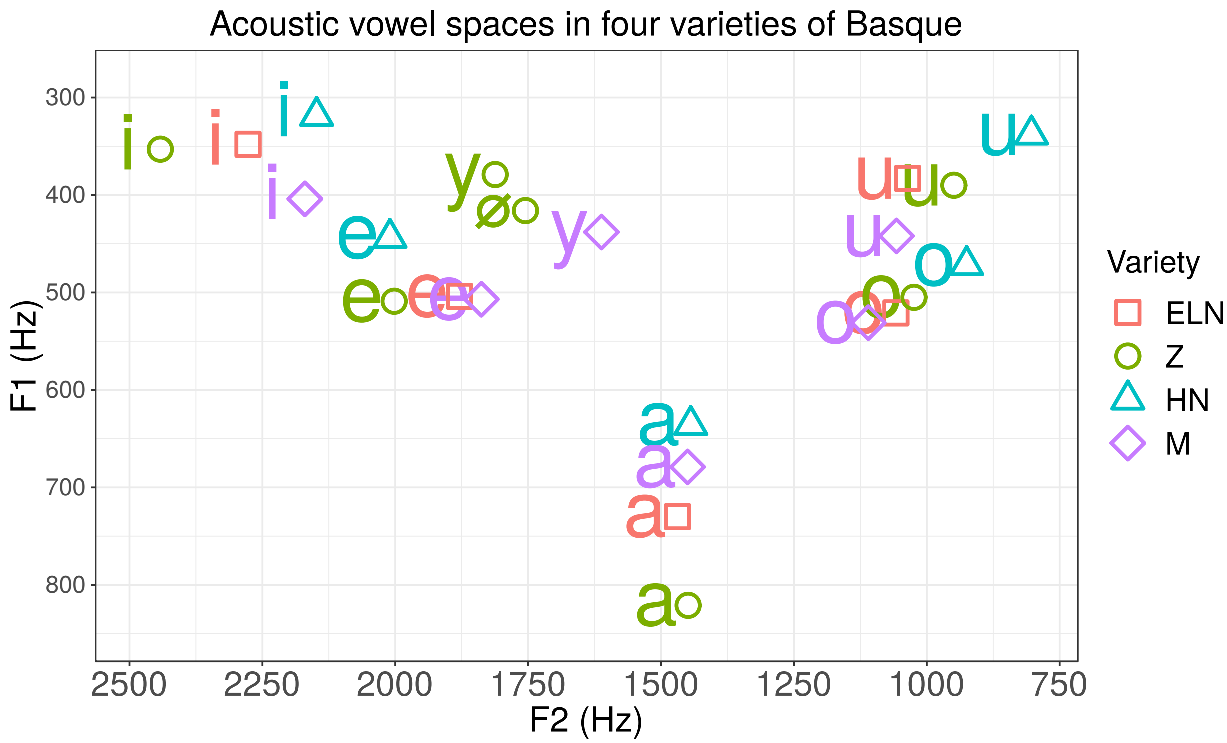


FIG. 4. (color online) F1 and F2 acoustic vowel spaces in Eastern Low Navarrese (ELN), Zuberoan (Z), High Navarrese (HN), and Mixean (M) Basque, based on findings from Urrutia *et al.* (1995), Pagola (1992), and the current study.

all similar box plot figures in the paper, mean values are displayed as white circles, median values are displayed as horizontal black bars, inward-facing notches display the standard error around the median (if the notches of two boxes do not overlap along the y-axis, this suggests that the medians are significantly different), the boxes denote the inter-quartile range (IQR; the middle 50% of the data), and the whisker lines denote 1.5 $\times$ the IQR; outliers have been removed to aid visualization. Average VOT values from the current and previous studies are displayed in Table IX. While the results suggest that there are differences between the three stop categories in Mixean Basque that are in the expected direction—

voiced stops are produced with negative VOT, unaspirated and aspirated stops are produced with positive VOT, and aspirated stops are produced with greater positive VOT values than unaspirated voiceless stops—the range of VOT values is substantially smaller in the Mixean variety compared to the Zuberoan variety. Only one of the previous studies investigated voiced stops (Gaminde *et al.*, 2002), for which they also observed negative VOT values. However, the range of average values (-105 ms to -101 ms) suggests a much longer interval of pre-voicing in the voiced stops of the Zuberoan variety than in the Mixean variety (range: -41 ms to -28 ms). Similarly, the range of average positive VOT values for aspirated voiceless stops (61 ms to 83 ms in Gaminde *et al.*, 2002 and 47 ms to 67 ms in Mounole, 2004) suggests a longer interval of aspiration in the Zuberoan variety than in the Mixean variety (range: 30 ms to 36 ms). However, the positive VOT values observed for the unaspirated voiceless stops of the Mixean variety are similar to those observed for Zuberoan in both Gaminde *et al.* (2002) and Mounole (2004).

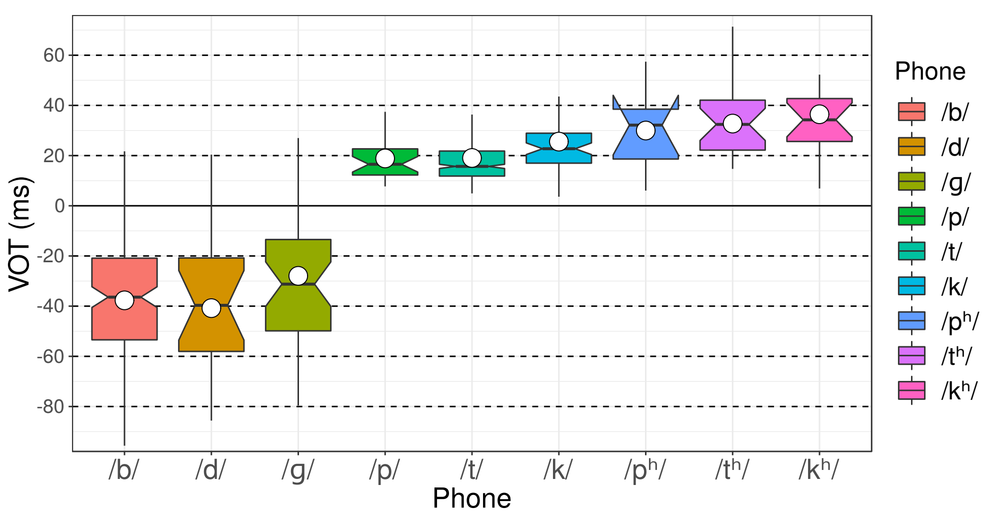


FIG. 5. (color online) Voice onset time (VOT; ms) values for stop consonants in Mixean Basque.

TABLE IX. Stop consonant voice onset time (VOT; ms) from Gaminde *et al.* (2002), Mounole (2004), and the current study.

Variety	Stop consonant								
	/b/	/p/	/pʰ/	/d/	/t/	/tʰ/	/g/	/k/	/kʰ/
Zuberoan (Gaminde *et al.*, 2002)	-102	20	61	-105	24	67	-101	27	83
Zuberoan (Mounole, 2004)		14	47		20	52		28	67
Mixean	-38	19	30	-41	19	33	-28	26	36

Both Gaminde *et al.* (2002) and Mounole (2004) report a distinction between unaspirated and aspirated voiceless stops in the Zuberoan variety, indicating a three-way voicing distinction. In our results for the Mixean variety, although the voiceless consonants that are (ostensibly) aspirated are indeed realized with overall greater positive VOT values than their unaspirated counterparts, the distinction between the two groups is not as large as has been reported for the Zuberoan variety. Recall from the introduction that stop aspiration has been lost in most Basque dialects and has been reported to show recession in the dialects that maintain it. Therefore, it is of interest for our current study to determine in an objective, data-driven manner whether a three-way contrast does exist in Mixean Basque. To this end, we performed clustering of speaker-normalized VOT values (z-scores) with the *mclust* R package (Fraley *et al.*, 2019), using the Bayesian Information Criterion (BIC) based on finite Gaussian mixture modelling to determine the optimal number of clusters present in the data. The results suggest that the overall distribution is indeed best described by three clusters/groups. The proportions of items belonging to these groups are shown in Figure 6.

In this figure, the three panels correspond to the three groups identified by the Gaussian clustering, and bars are shown in each panel for each of the nine consonant categories that are suggested by the orthographic representations. A given bar displays the percentage of the total number of items of given phone that are identified as belonging to the given cluster. The average VOT for the given consonant belonging to the cluster is displayed above each bar. By way of example, we take the clustering results for /g/: 81% of /g/ items were identified as belonging to Group 1, with an average VOT of -40 ms for these items; 12% of /g/ items were identified as belonging to Group 2, with an average VOT of 15 ms for these items; and 7% of /g/ items were identified as belonging to Group 3, with an average VOT of 34 ms for these items.

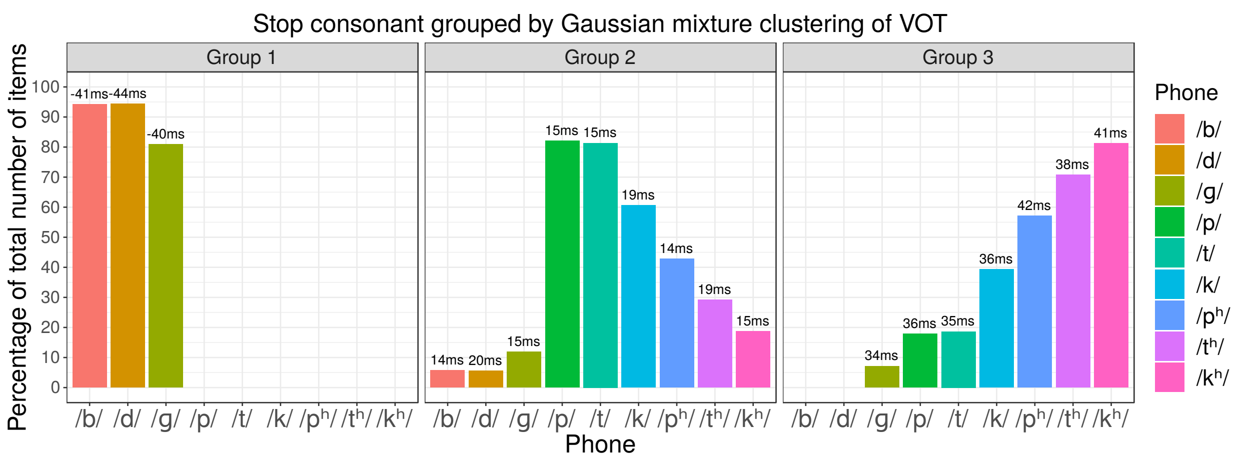


FIG. 6. (color online) Voice onset time (VOT; ms) values for stop consonants in Mixean Basque, separated into three clusters identified by finite Gaussian mixture modelling.

These results suggest that a three-way voicing contrast is indeed present in the variety. However, the classification of the observations based on these groups/clusters does not clearly delineate categories comprised solely of the three stop consonant groups /b, d, g/, /p, t, k/, and /p^h, t^h, k^h/. Group 1 consists of consonants with average negative VOT values in the range of -44 ms to -40 ms. Only /b, d, g/ items are included in this group, and the majority (81%–94%) of the items for these consonants are included in this group for each of the three consonants. This suggests that Group 1 represents voiced consonants, comprised solely of /b, d, g/ items, and that these /b, d, g/ items are nearly categorically realized with negative VOT (i.e., pre-voicing).

However, considerably more variation can be observed for Groups 2 and 3. Group 2 consists of consonants with average positive VOT values in the range of 14–20 ms. Interestingly, items from all nine stop consonants are realized with VOT values in this range. While the most prominent group of consonants in this cluster is indeed the unaspirated voiceless /p, t, k/ triad—82%, 81%, and 61% of the total number of items for these consonants, respectively—a small percentage of each of the voiced consonants /b, d, g/, as well as a much larger percentage of the aspirated voiceless /p^h, t^h, k^h/ are also produced with VOT values in this 14-20 ms range. Finally, Group 3 consists of consonants with average positive VOT values in the range of 34–42 ms. While there are no instances of voiced /b, d/ in this group, 7% of the total number of /g/ items are produced with VOT values in this range, as well as a higher percentage of unaspirated voiceless /p, t, k/—18%, 19%, and 39% of the total number of times for these consonants, respectively. However, the most prominent group of consonants in this third cluster is indeed the aspirated voiceless /p^h, t^h, k^h/ triad—57%, 71%, and 81% of the total number of items for these consonants, respectively.

Overall, the voice onset time results for the stop consonants suggest that there is a clear categorical distinction between voiced (negative VOT) and voiceless (positive VOT) consonants, but that the sub-distinction of aspiration vs. non-aspiration among the voiceless consonants displays a substantial degree of overlapping phonetic realizations. It has previously been shown that phonological stop aspiration can vary greatly from town to town within the Zuberoan variety (Michelena, 2011). This intra-dialectal variation, if also present in Mixean Basque, may provide a possible explanation for the phonetic variation observed here.

C. Results: Sibilants

Box plots of speaker-normalized CoG values for the sibilant consonants are displayed in Figure 7. The average values among all nine consonants range from 3365 Hz (for /ʒ/) to 5088 Hz (for /ts̻/). The group of voiced sibilants /ʒ, z̺, z̻/ are realized with the lowest CoG values. Given that the speech signals were band-pass filtered from 300 Hz to 19 kHz before spectral measurements were made, this pattern is not likely due directly to F0 energy. However, it is reasonable to speculate that energy associated with lower harmonics (energy that arises due to voicing) causes the overall spectral energy to shift towards lower frequencies. The group of voiceless laminal sibilants /s̻, ts̻/ are realized with the highest CoG values. It is of interest to note that both voiced and voiceless apical sibilants have similar CoG values to their palatal counterparts, suggesting a merger of the apical and palatal categories; this pattern is consistent for both fricatives and affricates. Regarding CoG values for fricative and affricate counterparts, there are no intra-pair differences among any of the three pairs /ʃ, tʃ/, /s̺, ts̺/, and /s̻, ts̻/. This suggests that, in each of the three cases, the place of articulation is consistent for the plain fricative and the fricative portion of its corresponding affricate.

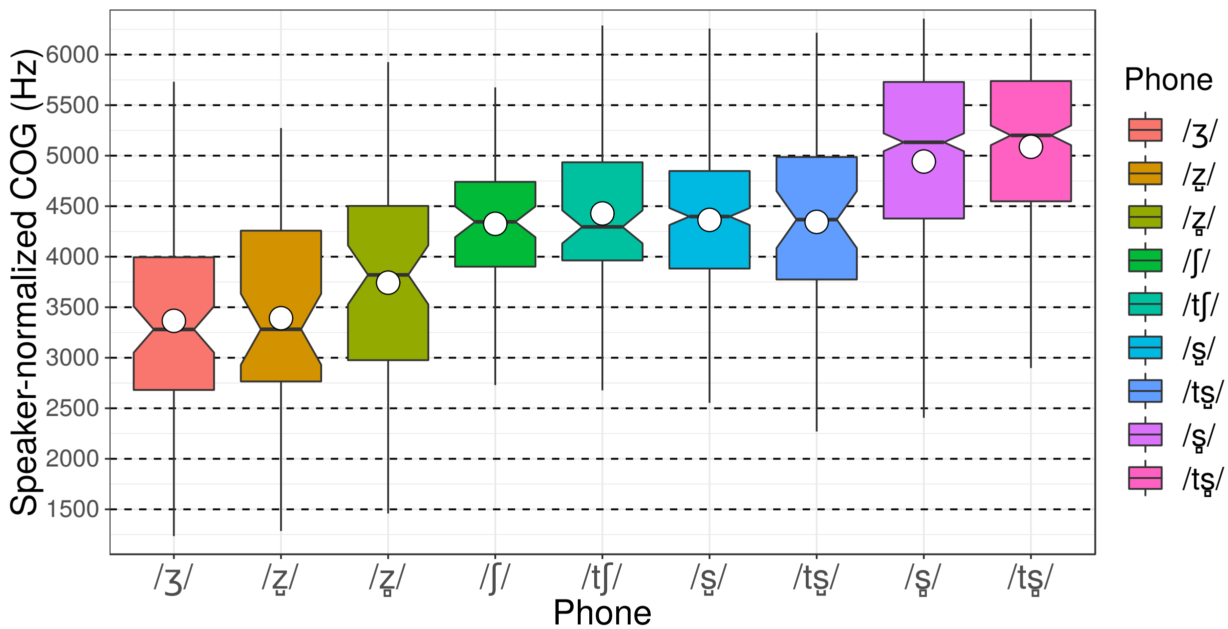


FIG. 7. (color online) Center of gravity (CoG; Hz) for sibilant consonants in Mixean Basque.

Average sibilant CoG values from the current and previous studies are given in Table X. There are several interesting patterns that can be observed in comparing our results to the CoG values that have been reported for other varieties of Basque. Firstly, the range of CoG values that we have obtained is much smaller than what has previously been reported for other varieties. In particular, our results show no indication of the comparatively high CoG values reported by Iglesias *et al.* (2016) (e.g, 14.5 kHz for /ts̻/) or Gandarias *et al.* (2014) (e.g., 13.1 kHz for /dz̻/). Unfortunately, since technical details about the CoG measurements are not provided in those studies, we are not able to ascertain whether this discrepancy is due to differences in the language varieties or to differences in experimental methodology. However, the results from the current study are congruent with CoG values that have been reported for voiceless sibilants in, e.g., Aleut, Apache, Chickasaw, Scottish Gaelic, Hupa, Montana Salish, and Toda (Gordon *et al.*, 2002). Secondly, although our results for CoG values of the fricatives and corresponding affricates suggest no differences in place of articulation in Mixean Basque, this is not the case for other studies that have researched fricative/affricate counterparts in Basque: Hualde (2010) reports relatively minor but consistently higher CoG values for affricates compared to fricatives (suggesting a slightly more anterior constriction for the affricates), Iglesias *et al.* (2016) reports higher CoG for the palatal affricate vs. fricative but lower CoG for the apical affricate vs. fricative, and Gandarias *et al.* (2014) reports higher CoG for the voiceless palatal affricate vs. fricative but lower CoG for the voiced palatal affricate vs. fricative. Finally, with the sole exception of the Bizkaian values reported in Beristain (2018b)—where we expect neutralization of these segments—all of the studies outlined here (including the current study) report lower CoG values for the apical sibilants compared to the laminal sibilants. This suggests that the apical sibilants may be produced with a post-alveolar (or even retroflex) place of articulation throughout the Basque language, including the Mixean variety researched here.

D. Results: Rhotics

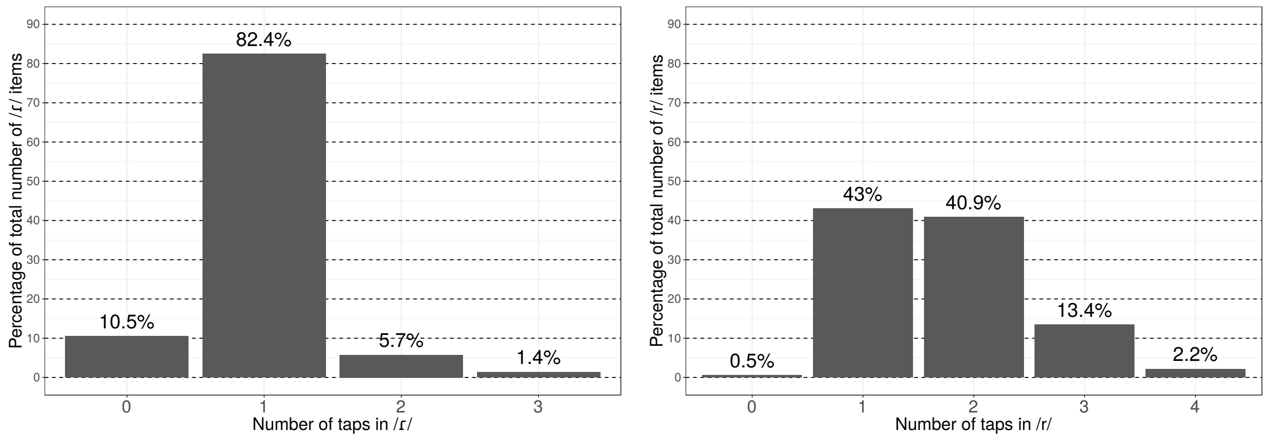
As mentioned in the introduction, the opposition between the two Basque rhotics (a tap and a trill) is only realized intervocalically. Rhotics do not occur word-initially, nor do they contrast in onset clusters or in codas. Thus, it is important to differentiate these three contexts for their analysis, as outlined in the current section.

TABLE X. Sibilant consonant center of gravity (CoG; Hz) summary from Hualde (2010), Iglesias *et al.* (2016), Gandarias *et al.* (2014), Muxika-Loitzate (2017), Beristain (2018b), and the current study.

Variety	Sibilant consonant										
	/s̻/	/ts̻/	/s̺/	/ts̺/	/ʃ/	/ʧ/	/ʒ/	/dʒ/	/z̻/	/dz̻/	/z̺/
High Navarrese Hualde (2010)	6645	7183	4173	4343	3531	3829					
High Navarrese Beristain (2018b)	7914		5117								
Gipuzkoan Iglesias *et al.* (2016)	14,452	14,517	8081	6951	5966	7757					
Gipuzkoan Beristain (2018b)	7450		7160								
Bizkaian Gandarias *et al.* (2014)		9469	6500		6588	10,383	8033	5394		13,136	
Bizkaian Muxika-Loitzate (2017)	6610		6242		5770						
Bizkaian Beristain (2018b)	5636		5925								
Mixean	4942	5088	4364	4345	4326	4428	3365		3743		3391

1. Intervocalic rhotics

The results for the number of lingual contacts produced in the tap /ɾ/ and in the trill /r/ in intervocalic position are shown in Figure 8. The bars in this figure represent the percentage of total items (*y*-axis) that occur for a given number of lingual contacts (*x*-axis). For the intervocalic tap /ɾ/, the majority of items (82.4%) are produced with a single lingual contact, as expected for the phonetic realization of a tap. A small portion of the items (10.5%) are produced without any measured lingual contact; these realizations may



(a) (b)

FIG. 8. Relative proportions of the estimated number of lingual contacts/taps in intervocalic /ɾ/ (left) and /r/ (right) items in Mixean Basque.

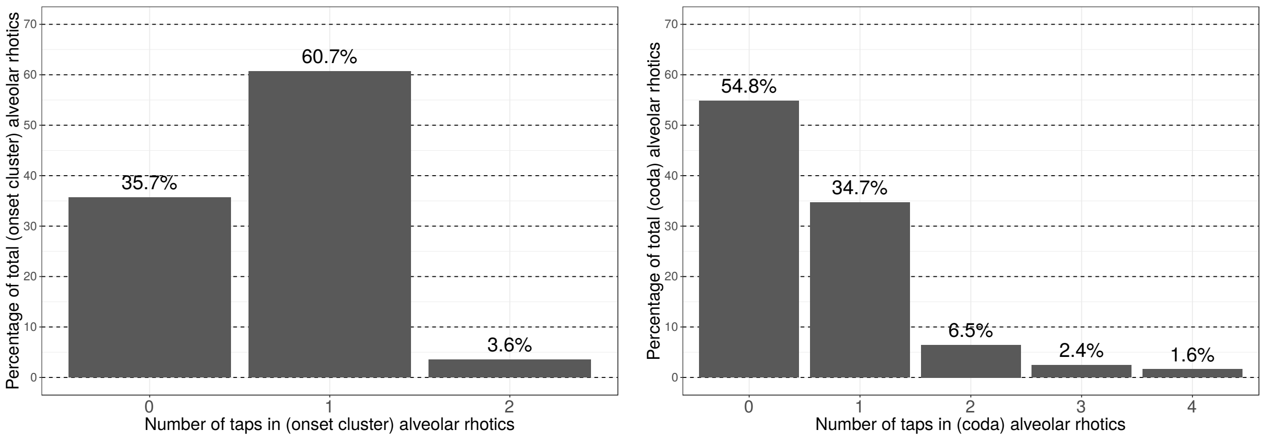
represent occurrences of the allophones [ɹ͡ɹ, ɹ̝], as reported by Gaminde *et al.* (2016) for Bizkaian Basque. An even smaller portion of the items (7.1%) are produced with multiple contacts, suggesting that the tap /ɾ/ is sometimes (but infrequently) produced as a trill in the Mixean variety of Basque. For the intervocalic trill /r/, there is a nearly equal proportion of items realized with a single contact (43%) as of items realized with two contacts (40.1%). The high proportion of single-contact items is surprising, given the fact that trills are characterized by multiple articulator contacts; this result suggests a possible merger in progress of /r/ to /ɾ/ in Mixean Basque. Nevertheless, slightly over half of the total number of /r/ items (56.5%) are produced with multiple lingual contacts (i.e., two or more taps). A single item produced by one male speaker (0.5% of the total data) was produced with no measured lingual contacts; this item was verified manually by the second author, and his perception of the segment was congruent with the automated report of no lingual taps in this particular item.

2. *Onset cluster and coda rhotics*

The results for the number of lingual contacts produced in alveolar rhotics in onset clusters and in coda position are shown in Figure 9. In comparison to the intervocalic environment, the occurrence of alveolar rhotic items produced without any lingual contact is much greater in the onset cluster and coda environments. 35.7% of /ɾ, r/ items are produced without any lingual contact when they occur in onset clusters, while the majority of alveolar rhotics (54.8%) are produced without any lingual contact when they occur in coda position. However, in both environments, some of the alveolar rhotic items are produced with at least one tap. In onset clusters, the majority of items (60.7%) are produced with a single tap, and a small proportion of items (3.6%) are produced with two taps; no items are produced with three or more lingual taps. In coda position, while the majority of items are produced without any lingual contact, a substantial proportion of alveolar rhotics are produced with one (34.7%) or multiple (10.5%) taps, including rare cases of three and four taps.

V. DISCUSSION

Based on the previous literature, we expected to find six vowel categories in Mixean Basque: the common Basque vowels /a, e, o, i, u/, and the high front rounded vowel /y/, as found in Zuberoan. Our acoustic analysis confirms that there are six vowels in Mixean. Nevertheless, our results suggest that the Mixean vowel system is characterized by two front vowels (/i/ and /e/), two central vowels (/y/∼[ʉ] and /a/), and two back vowels (/u/ and



(a) (b)

FIG. 9. Relative proportions of the estimated number of lingual contacts/taps of alveolar rhotics in onset clusters (left) and coda (right) in Mixean Basque.

/o/). The retraction of Mixean /y/ has been auditorily described as closer to /ø/ (Haase, 1992, p. 29), although our results suggest that the sixth vowel found in Mixean is better represented as [ʉ], a segment not found in any other variety of the Basque language. In addition, all high vowels in Mixean seem to be comparatively lower than their equivalents in other Basque dialects. The observation that Zuberoan high vowels are lower than those found, for instance, in French has been made by other authors as early as Larrasquet (1932), but our results for Mixean point to even lower high vowels than these described by Urrutia *et al.* (1991) for Zuberoan Basque. Thus, Mixean high vowels /i, y, u/ are actually articulated with mean formants close to the values expected of [e, ɵ, o].

Regarding Mixean stops, our study has found evidence that there is still a three-way laryngeal distinction in the language (pre-voiced, plain voiceless, and voiceless aspirated). Nevertheless, the mean VOT values that resulted from our study are less extreme than these reported by previous authors for the Zuberoan dialect. Although the finite Gaussian mixture modelling applied to our data suggested the presence of three stop series, the clusters that resulted from this classification did not consistently reflect the orthographic notation. These two observations suggest that the three-way distinction is not as strong in Mixean Basque as has been reported for Zuberoan Basque, and that distinctive aspiration is perhaps being lost in this variety, as has arguably occurred in other Basque varieties (Egurtzegi, 2018a).

Within sibilants, we did find a categorical difference between apical and laminal sibilants, but our results are not consistent with the most general description of the place of articulation of sibilant segments (namely, apico-alveolar, lamino-alveolar and alveolo-palatal). As the rest of the studies outlined in this paper, our study found lower CoG values for the apical sibilants than for the laminal sibilants, which is in line with the observation that apical sibilants may be articulated with a post-alveolar (or even retroflex) place of articulation, as suggested by a number of previous descriptions. However, no differences in CoG were observed between the apical and alveolo-palatal sibilants, suggesting a merger in place of articulation between the two sets of segments. This process could involve one of three scenarios: (1) a merger of apical to alveolo-palatal, as described in Hualde (2010); (2) a merger of alveolo-palatal to apical; or (3) a merger of both categories towards an intermediate place of articulation. In comparing our CoG measurements to the values reported in other studies, the CoG values for the apical sibilants are similar to those reported by Hualde (2010) for High Navarrese; however, the values for the alveolo-palatal sibilants are lower in High Navarrese than those observed in the current study. We believe that these results suggest that the alveolo-palatal sibilants have merged to apico-alveolar in the Mixean variety, i.e., scenario 2 above. Finally, unlike previous reports, we did not find CoG differences between any given fricative and its affricate counterpart, suggesting that fricative and affricate counterparts are produced with the same place of articulation in Mixean Basque.

We expected to find an opposition between a tap and a trill in intervocalic position, as in other Basque dialects. The results from our study suggest that, in Mixean, this opposition is not as strong as in other Basque dialects. While the number of intervocalic productions of the phonological tap with more than one lingual contact was not very high (7.1%), the percentage of productions of the phonological intervocalic trill with a single tap was much higher than expected (43%). Although the majority of the intervocalic trills were actually trilled (56.5%), the unexpectedly high number of trills realized as a tap intervocalically points in the direction of an incipient merger of the two rhotics in Mixean Basque. Following the more general descriptions of Basque rhotics, we may have expected the rhotics in neutralizing contexts (i.e., onset clusters and codas) to be articulated as shorter trills (i.e., two lingual contacts). However, our study suggests that the most common realization of onset-cluster rhotics involves one tap (60.7% of all items, and 35.7% with no taps) while coda rhotics are most frequently produced with no taps (54.8% of all items, and 34.7% with one tap). These results suggest that neutralized rhotics are produced as taps or approximants in Mixean, and that coda position is the most frequent context for the realization of approximant/fricative rhotics, followed by onset clusters. Finally, regarding the place of articulation of Mixean rhotics, while some of the speakers produced a number of uvular articulations, none of them limited their rhotics to uvular segments. This observation is based on manual transcription and concomitant perception by the first author (a native speaker of Basque). This finding contrasts with observations by Gaminde *et al.* (2017), who consistently found uvular articulations in the speakers from eastern Basque dialects. However, it is worth mentioning that, while the speakers in their study were of young age, the participants in our study encompassed speakers from a much older generation, so that the spread of uvular rhotics in eastern Basque dialects can potentially be viewed as a recent innovation.

VI. CONCLUSION

This study has presented a general description of an endangered variety of Basque, namely Mixean Low Navarrese, via acoustic analyses of most segments in its phonological inventory. Not only has it highlighted the importance of describing minority varieties, but it has also underlined the uneven nature of the acoustic studies on the Basque language: while studies on vocalic inventories and sibilants are fairly common, the rest of the segments of the language are understudied, and no general acoustic description of any variety (or the standard language) can be found in the literature. Important results of this study include the first acoustic description of a centralized rounded vowel in Mixean Basque, a data-driven confirmation of the maintenance of the three-way stop distinction, evidence in support of a merger of the series of alveolo-palatal sibilants to the apico-alveolar sibilant series, the description of an incipient merger of rhotics, and the realization of rhotics in neutralizing positions with one or even no lingual contacts.

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