NASALIZED FRICATIVES IN COATZOSPAN MIXTEC[1]

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1. Introduction. A central focus of contemporary linguistic study involves the search for universal principles and properties of human language. In phonology and phonetics, important research along these lines centers on the determination of what can constitute a possible speech sound in natural language (see Catford 1977, Lindblom 1990, Maddieson 1997, and Ladefoged and Everett 1996). Phonetic data from underdescribed (and often endangered) languages are crucial to this enterprise, given that a broad range of cross-linguistic data provides a rich and necessary testing ground for putatively universal hypotheses. This paper investigates the issue of possible speech sounds through a consideration of nasalization in Coatzospan Mixtec (henceforth CM), an Otomanguean language of Southern Mexico.

Using data collected in the field, I provide aerodynamic evidence for the existence of phonetically nasalized, voiceless fricatives. This finding is important in two respects. First, the data challenge standard assumptions regarding the universal possibilities of nasalization. Second, they call attention to the limitations of transcription alone (and to the benefits of incorporating technology) as a means of phonetically documenting underdescribed languages.

In **2** I provide a brief background on CM and a description of the data under consideration. In **3** I discuss the data acquisition process and present aerodynamic evidence for the nasalization of voiceless fricatives in CM. In **4** I conclude with a discussion of the implications of the findings for our understanding of what can constitute a possible speech sound.

2. Background. Coatzospan Mixtec is spoken in the village of San Juan Coatzospan, in northern Oaxaca, Mexico. Among the most geographically isolated of at least 22 mutually unintelligible varieties of Mixtec, the village is surrounded primarily by Mazatec-speaking communities and, according

[1] I would like to express my thanks to a number of people for their feedback on the work under discussion here. These include Pris Small, Megan Crowhurst, Pilar Piñar, and Diana Archangeli, whose NSF grant #BNS9023323 provided support when these data were collected. I am especially grateful to Njau Piña for his help in the field and without whom this work would not have been possible, and to Ian Maddieson and another, anonymous reviewer for their helpful comments and suggestions. All errors are, of course, my own.

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TABLE 1

CM CONSONANT INVENTORY

	Bilabial	Interdental	Alveolar	Palato-alveolar	Velar	Labio-velar
Stops	[*p*]		*t*		*k*	k^w
	[*mb*]		*nd*		[*ŋg*]	[$ŋg^w$]
Affricates			*ts*	[*tʃ*]		
			[*ndz*]	[*ndʒ*]		
Fricatives	*β*	*ð*, [$ð^j$]	[*s*]	*ʃ*		
Liquids			*l*, [*r*]			
Nasals	*m*		*n*	*ɲ*		

to Josserand (1982), only two other Mixtec languages exhibit over a 25% rate of mutual intelligibility with CM. By the most recent estimate, there remain approximately 2,000 CM speakers (Small 1990), and prior to Gerfen (1999), there existed no published data on the phonetics of CM, while only one brief sketch (Pike and Small 1974) provided any information on the phonological properties of the language.

As first described by Pike and Small (1974), CM has 22 consonant phonemes. Following Gerfen (1999), these are presented in table 1, with more marginal contrasts enclosed in brackets. The vowel system consists of six phonemic vowel qualities, as shown in table 2.

Note that the number of vocalic contrasts is actually larger, since vowels surface as both contrastively nasalized and/or laryngealized, as illustrated by pairs such as *kḭ:* 'put on' vs. *kḭ̃:* 'go'. In addition, tone is lexically contrastive (e.g., *là:* 'bird' vs. *lǎ:* 'flower'), yielding an even larger number of potential vowel contrasts under a traditional phonemic view.[2]

In this paper, I focus on the aspect of CM phonology that has received the most attention in the phonological literature: the morphologically induced system of nasal harmony. Specifically, the second-person familiar (2FAM) is formed by a process of regressive vowel nasalization within a CM COUPLET, a term which derives from the divocalic (or, in more contemporary terms, bimoraic) shape of open-class morphemes across the Mixtec languages (see Pike 1948). The Mixtec couplet has two canonical shapes: [CVCV] and [CVV]. Of relevance to the ensuing discussion are the [CVCV]

[2] There is one restriction on the free combination of underlying or lexical nasalization with the vowels. Specifically, there are no words in which /o/ is contrastively nasalized. Nasalized [õ] does arise as a result of the morphological nasalization process discussed below that marks the second-person familiar. See Gerfen (1999) for extensive discussion of the distributional restrictions on both contrastive glottalization and nasalization. Pike and Small (1974) provide a discussion of the underlying tone contrasts, with special attention to the phonological downstep and sandhi.

TABLE 2

CM VOWEL INVENTORY

i	*ɨ*	*u*
e		*o*
	a	

forms, since the evidence for the existence of phonetically nasalized voiceless fricatives derives from the interaction of the medial consonant with the nasal harmony process.

The basic facts of the nasal harmony process are straightforward: 2FAM nasalization involves the right-to-left propagation of nasalization from vowel to vowel. Crucially, the voicing status of medial consonants in [CVCV] forms conditions the extent of nasal propagation. If voiced, medial consonants are transparent to nasalization, and both vowels of a couplet are nasalized. This is illustrated in (1).

(1) Transparency: both V1 and V2 nasalized
- (1*a*) [βiðe] 'wet' → [βĩðẽ] 'you (FAM) are wet'
- (1*b*) [kuβi] 'die' → [kũβĩ] 'you (FAM) will die'
- (1*c*) [tʲɨ̰βi] 'push' → [tʲɨ̰̃βĩ] 'you (FAM) will push'
- (1*d*) **tɨ̰βĩ*, **tɨ̰̃βi*, etc.

By contrast, voiceless medial consonants are opaque to harmony, and nasalization thus affects only the final vowel of a couplet. Examples are provided in (2).

(2) Opacity: nasalization restricted to V2
- (2*a*) [kṵtʲu] 'hoe' → [kṵtʲũ] 'you (FAM) will hoe'
- (2*b*) [kṵtsi] 'bathe' → [kṵtsĩ] 'you (FAM) will bathe'
- (2*c*) [kḭʃi] 'come' → [kḭʃĩ] 'you (FAM) will come'
- (2*d*) [ka̰ka] 'walk' → [ka̰kã] 'you will walk'
- (2*e*) **kã̰kã*, **kã̰ka*, etc.

The proper phonological treatment of transparency and opacity has been a matter of considerable debate (cf. Poser 1980, Cole 1987, Trigo 1988, Piggott 1992, and Gerfen 1994 for various rule-based autosegmental treatments; also Homer 1995 and Gerfen 1999 for Optimality-based approaches). The focus of this paper, however, is on the phonetic implementation of nasality during the production of intervening voiceless fricatives. As seen in (2*c*), these prevent nasalization from reaching the initial vowel of a couplet. Of primary importance here, though, is that aerodynamic evidence indicates that the fricatives which block harmony can themselves be nasalized. I turn to this evidence in **3**.

3. Aerodynamic evidence for nasalized voiceless fricatives. Intuitively, nasalized voiceless fricatives make for improbable speech sounds. Ohala and Ohala (1993) translate this intuition into a phonetic principal, claiming that buccal obstruency is universally incompatible with velum lowering. Their formulation is stated in (3) (see also Ohala 1975).

(3) THEOREM A: The velic valve must be closed (i.e., the soft palate must be elevated) for an obstruent articulated further forward than the point where the velic valve joins the nasal cavity and the oral cavity (Ohala and Ohala 1993:227).

From an aerodynamic perspective, the logic of Theorem A is persuasive, given that velum lowering vents air through the nasal passages, thus bleeding off the pressure buildup necessary for obstruent production. In the case of fricatives in particular, velic aperture renders it particularly difficult to generate turbulent airflow at the point of constriction.

Cohn's (1993*b*) survey of reported cases of nasalized continuants provides only a few potential counterexamples to Theorem A. Most involve nasalized voiced fricatives such as [ṽ] in UMbundu (Schadeberg 1982) or [β̃] in Waffa (Stringer and Hotz 1973). In addressing such claims, Ohala and Ohala reason that these sounds are better analyzed as frictionless nasalized continuants, i.e., they speculate that the effect of velic aperture is to turn sounds such as [β̃] into sonorants.[3] However, Cohn also mentions reports of nasalized voiceless fricatives in Ìgbò (Carnochan 1948 and Williamson 1969), while Ohala and Ohala themselves note Ternes's (1973) claim that there are nasalized voiceless fricatives in Scots Gaelic. It is important to understand that these claims have always been based entirely on impressionistic evidence. If confirmed instrumentally, however, Ohala and Ohala recognize that Theorem A would be falsified. Bearing this in mind, I turn now to instrumental evidence for the nasalization of voiceless fricatives in CM.

3.1. Data collection and assumptions. Nasal airflow studies are valuable in that they provide a noninvasive way to monitor velum activity during speech. In simple terms, we can assume that the phonetic dimension of velum height and the phonological feature [nasal] stand in a fairly direct relation: a lowered velum implements nasality, while a raised velum implements orality. All else being equal, we thus expect to find increased nasal flow with velum-lowering gestures and decreased flow with velum raising. In this sense, flow data provide a profitable means of monitoring the implementation of phonological nasality and orality (see also Cohn 1990; 1993*a*

[3] See also Gerfen (1999) for instrumental evidence of nasalized [β̃] and [ð̃] in CM.

for nasal flow studies of English, Sudanese, and French; and Huffman 1989; 1993 for studies of Yorùbá and Akan).[4]

The data here were collected using the Macquirer system, developed at the UCLA Phonetics Laboratory. The choice of this system, instead of using a Rothenberg-type split flow mask (cf. Cohn 1990 and Huffman 1989) was based on availability. The Macquirer system was designed for portability in order to be able to be used in field settings.[5] The system consists of a box containing a pressure transducer that is connected to an 8-bit external A/D converter. Speakers place a small foam plug or nasal olive in their nostril (an E-A-R plug of the kind used in audiology research), while wearing a close-talking microphone connected to a tape recorder from which the signal is also fed to the A/D converter. The nasal olive is connected to the pressure transducer via a small, flexible Tygon tube. As the speaker talks, the system samples and aligns the transducer's response to the nasal airflow (sampled at 480 Hz) with the audio signal (sampled at 11 kHz) and stores them on a Macintosh computer. Figure 1 gives a view of the setup.

In order to avoid the problem of uncalibratable flow due to the lack of resistance at the open nostril, speakers also closed the unplugged nostril with a finger while speaking. As can be seen in figure 1, I provided a fixed resistance to flow by inserting a "T" in the tube between the olive and the transducer. The "T" was connected to a long, thin plastic tube (about three feet). Though I did not have a pump and was thus unable to calibrate the system in the field, I did have access to a pump at the UCLA Phonetics Lab[6] and I calibrated the system at 250 ml/sec of flow. And despite the fact that the response of the transducers can vary slightly with different weather conditions, I have provided a scale reflecting the UCLA calibration in order to give the reader a rough approximation of flow rate.

The forms under discussion in this paper were included as part of a larger list of 35 CM words. Following the methodology of Cohn (1990; 1993*a*), the data were collected by having speakers repeat a target word in a nonnasal carrier phrase. Since CM has no standard orthography, I reviewed the experimental list with each speaker in order to guarantee that there was no misunderstanding about what lexical item the speaker was being asked

[4] Additional factors that must also be kept in mind are oral impedance and glottal width, both of which can affect the rate of nasal airflow independently of changes in velo-pharyngeal port size (see Huffman 1989, Cohn 1990, and Krakow and Huffman 1993 for discussion). These factors do not play a significant role, however, in the data under consideration here.

[5] For general discussion of collecting aerodynamic data in the field, see Ladefoged (1993; 1997). See also Gerfen (1994; 1999) for a more detailed discussion of the experimental setup used here, and Ladefoged and Maddieson (1996) for published pressure and flow data on other languages, collected with the Macquirer system.

[6] Special thanks to Peter Ladefoged for assistance with this task.

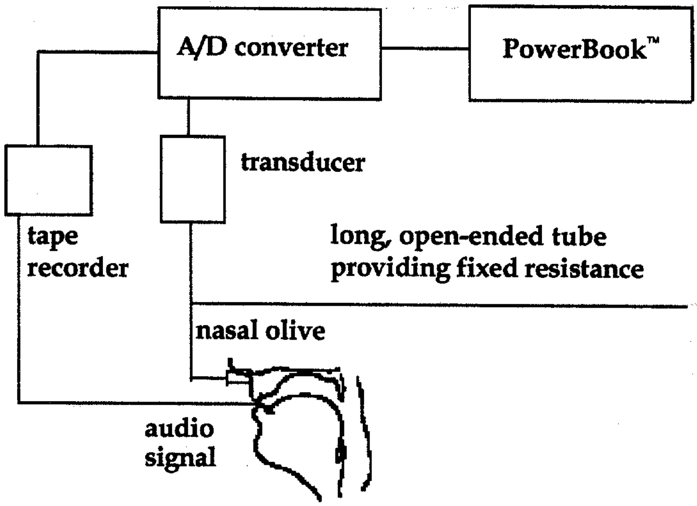

FIG. 1.—Data collection setup.

to produce. I presented the words to the speakers by using a modified version of Spanish orthographic conventions, with which the speakers were familiar. The complete list is provided in narrow phonetic transcription in Appendix A.

The data under discussion in this paper were selected from the 2FAM paradigm, which provides a particularly useful set of experimental stimuli, since it affords a set of minimally distinct oral vs. nasalized forms. For example, a base word containing no nasalized vowels, such as [ki̯ʃi] 'come', is nasalized in the second-person familiar to yield [ki̯ʃĩ] 'you (FAM) will come'. In this way, non-nasalized base forms serve as oral controls for their nasalized counterparts. Though the data were not randomized, I did not present speakers with oral forms immediately preceded or followed by their nasal counterparts. Finally, speakers were somewhat uncomfortable with reading through the word list without making errors. To solve this problem, I recorded multiple tokens of a single item at one time before moving on to another word. All of the target items were produced five times by each of the speakers in the non-nasal carrier phrase [ka̯u-u WORD tʃe-βaa] 'I will write WORD tomorrow'.[7] Data were recorded for three female speakers

[7] The transcription of [tʃe-βaa] reflects the women's speech pronunciation in which /t/ is predictably realized as [tʃ] before front vowels. See Gerfen (1999) for discussion of CM palatalization and palatograms.

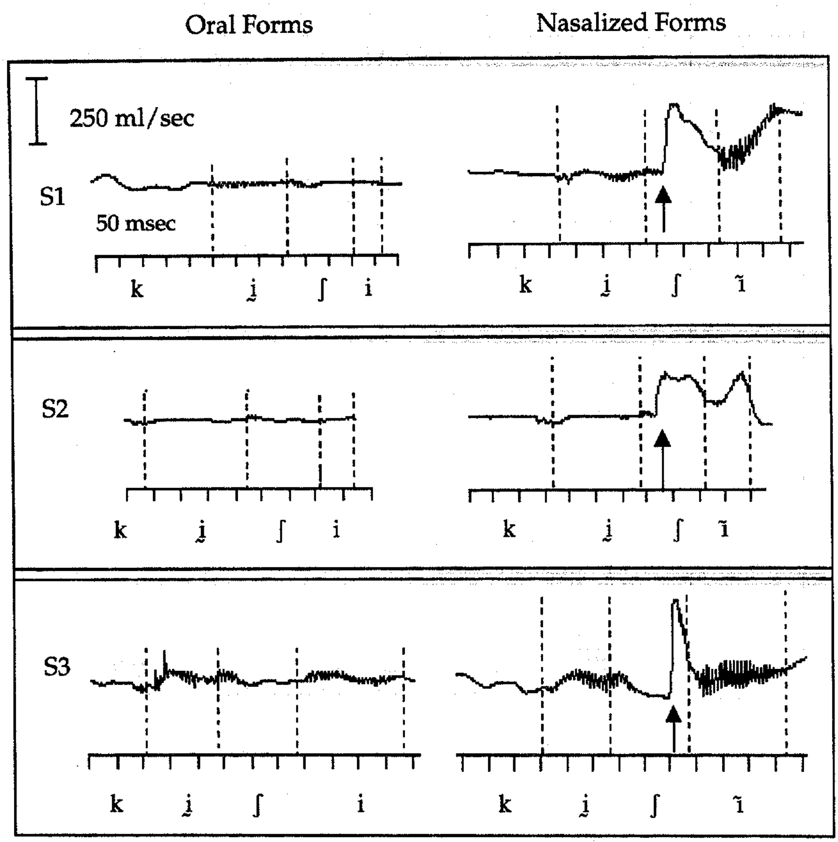

FIG. 2.—Oral versus nasalized forms.

(S1–S3), approximately 21 (S3), 30 (S1), and 45 (S2) years old at the time of recording.

3.2. Evidence for fricative nasalization. Evidence for the nasalization of voiceless fricatives emerges clearly when we contrast the production of [ʃ] in the oral form [ki̯ʃi] 'come' with its nasalized counterpart [ki̯ʃĩ] 'you (FAM) will come'. Consider, for example, the nasal flow traces in figure 2, where an oral and a nasalized form are presented for each speaker.

As we can see in each of the nasalized couplets on the right of the figure, the medial fricative is opaque; that is, it prevents leftward propagation of nasality to the initial vowel of the form. Nevertheless, two related observations are of importance. First, the sharp onset of nasal flow (marked by arrows) indicates that all three speakers exhibit anticipatory velum lowering prior to the offset of the fricative, with two speakers—S1 and S2—exhibiting between 80–90 msec of anticipatory velum lowering prior to the onset of the final nasalized vowel.

Second, the oral forms serve as controls, which prevent us from attributing the presence of nasal flow during the production of the fricative in the nasalized form to other factors, such as a combination of the generally large glottal width employed during the production of voiceless fricatives and some degree of leakage at the velo-pharyngeal port. If this were the case, we would expect to see a similar spike in nasal flow during the [ʃ] of the oral controls. No such spiking is found for any of the recorded oral tokens. Instead, it is the morphological nasalizing context which triggers anticipatory velum lowering in voiceless fricatives.

The stack bar graphs in figure 3 provide a view of the timing of the onset of nasal flow with respect to the medial fricative in the nasalized form [kḭʃĩ] 'you (FAM) will come' for all five repetitions for each speaker, thus affording a clear sense of the variability both within and across speakers. The darker shading marks the portion of the fricative that is realized prior to the onset of nasal flow, while the lighter gray shading indicates the portion of the fricative that overlaps with the presence of nasal airflow, i.e., the part of the fricative that is coincident with velic aperture. Note that both S1 and S2 exhibit anticipatory flow in all tokens, though the onset of flow is quite variable. S3 also exhibits anticipatory flow prior to the onset of voicing in the following nasalized vowel in four of the five tokens. However, in her case, we see that velum lowering is more closely timed with respect to the offset of the medial fricative.

Table 3 provides a table of the approximate peak values in ml/sec of the nasal flow measured in the fricatives, based on the calibration made at the UCLA Phonetics Lab.[8]

Interestingly, John Ohala (personal communication) challenges the interpretation of the flow data described here. In particular, he notes that since the other nostril is closed, the spiking present during the production of these fricatives may simply be an artifact of slight velum raising (but not opening) which compresses the air trapped in the nasal cavity between the velum and the nostrils. (See Ohala, Solé, and Ying 1998 for further debate on this issue.)

There are, however, at least four strong arguments against Ohala's interpretation of the facts. First, if we consider the volume velocity (as extrapolated from the pressure increase registered at the transducer), we see that volume velocity is higher in nasalized fricatives than in vowels (except in

[8] Note that values of 355 ml/sec represent peak values taken in cases in which the signal was clipped.

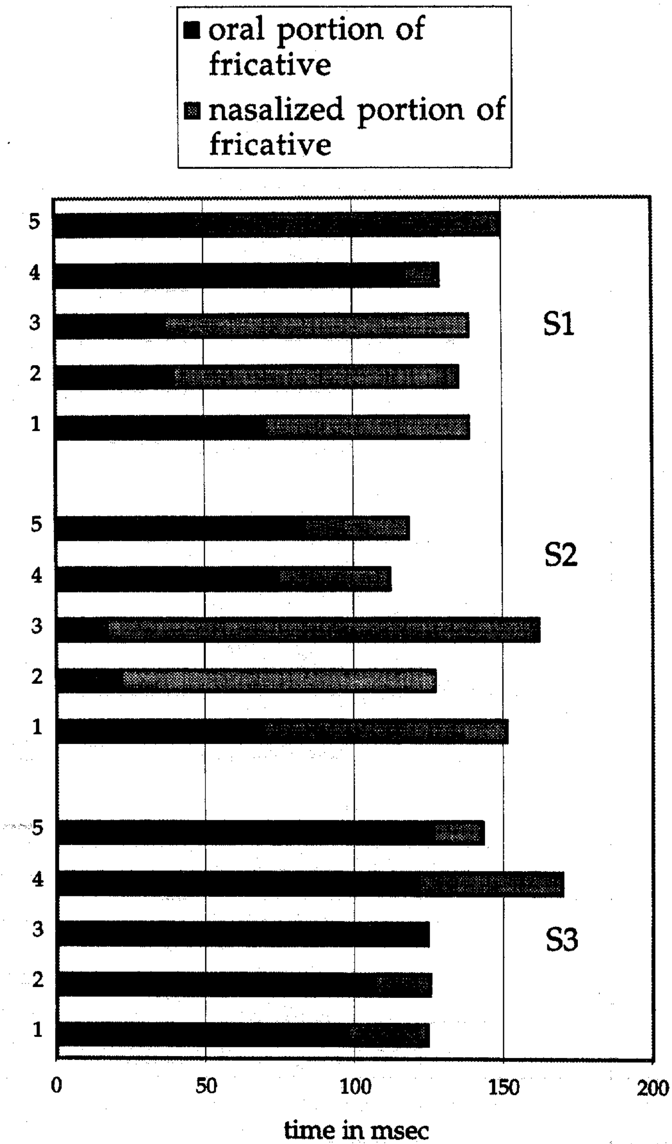

FIG. 3.—Stack bar graphs showing portion of [ʃ] realized with nasal flow by speaker and repetition.

TABLE 3

APPROXIMATE NASAL FLOW RATE MAXIMA IN ML/SEC BY SPEAKER AND REPETITION

Repetition	S1	S2	S3
1	355	261	253
2	355	270	102
3	267	193	n.a.
4	329	219	355
5	355	227	355

some cases at the offset of the fricatives). In Ohala's view, the spike in flow during the fricatives is to be attributed to a velum raising gesture. However, if we consider the amount of air volume registered in the trace, it is highly unlikely that this amount of air could be moved by a slight raising gesture of the velum when it is already in a position to seal the velo-pharygeal port. By contrast, greater airflow through the nose is readily explained by greater flow resistance in the oral cavity during the articulation of the fricative.

Second, it is important to note that the nasal flow is sustained in a number of the tokens, particularly the example from S2 in figure 2. Ohala's view is predicated on assuming a one-time raising gesture of the velum. Such a scenario cannot plausibly account for the flow remaining high and relatively flat for such a long duration. (Note that S3's token in this figure is more ambiguous in this regard.) Third, Ohala's interpretation makes incorrect predictions regarding the direction of flow at the offset of the fricatives in question. Specifically, if we are to explain the increase in registered flow as a consequence of the fact that the nasal tube constitutes an effectively closed system responding to changes in nasal cavity volume, then we predict that the nasal flow trace should show a negative flow toward the end of the fricative as the velum begins to lower in preparation for the release into a nasalized vowel. None of the tokens illustrated, however, exhibits such a pattern. Finally, anticipating the discussion in **3.3** below, the pattern seen in the "transparent" [ʃ] in figure 9 completely rules out explanations of this sort, because the velum is obviously in a lowered position during the first vowel and at the onset of the fricative. In fact, it is useful to note how sharp the rise in flow is at the onset of nasalization in the first vowel in this token, where velum raising is simply not an option for accounting for the "spike" in flow. In short, the data show that voiceless fricatives in this context can be phonetically nasalized.[9]

[9] I am grateful to Ian Maddieson for detailed and helpful feedback regarding the issues addressed in the two paragraphs above.

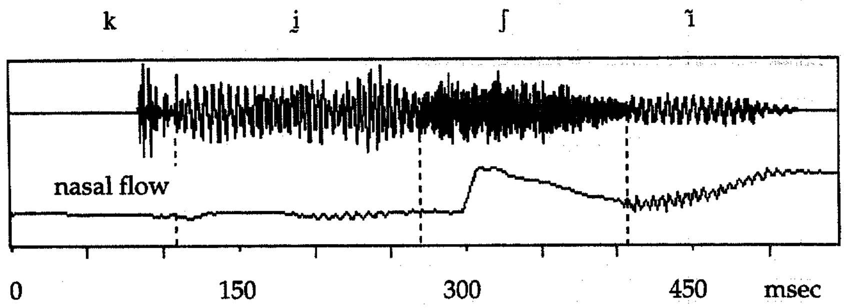

FIG. 4.—Nasalized [kɨʃĩ] 'you (FAM) will come' produced by S1.

If the data here are to successfully challenge Theorem A, however, an additional question must be addressed. Above, we saw that Ohala and Ohala (1993) take nasalized fricatives [β̃] or [ð̃] to be frictionless continuants. Though unambiguously drawing a line between frictionless continuancy and frication is nontrivial, it is important to establish that nasalized tokens of [ʃ] remain fricatives, despite velum lowering. This issue can be addressed by considering data such as that in figure 4.

There, the nasal flow trace is accompanied by the acoustic signal of a nasalized token of [kɨʃĩ] 'you (FAM) will come'. Two observations are of interest. First, the waveform exhibits the pattern of random energy associated with the production of voiceless fricatives. Second, this pattern is sustained throughout the duration of the fricative, despite the onset of nasal flow prior to the halfway point of the fricative. [ʃ] is thus not realized as a frictionless continuant in this context. Note, as well, that although the amplitude of the fricative declines, this is not simply an effect of nasalization but is also attributable to adjustment in glottal width. Thus, a similar picture emerges in non-nasalized contexts, as seen in figure 5.[10] Figures 6 and 7 provide comparable examples for S2.

Having considered the behavior of opaque [ʃ], it is interesting to note that the same pattern of anticipatory nasalization is found for medial voiceless affricates. This can be seen clearly in the nasalized token in figure 8, in which a spike in nasal flow is coincident with the release of stop closure and the onset of the fricated portion of the affricate. On the basis of such data, we can conclude that velic aperture does not render buccal obstruency impossible.

[10] As John Ohala (p.c.) has pointed out to me, one potential confound in interpreting the data is the fact that the nostril without the nasal olive was plugged during data collection. As a result, this will result in a general closure at the nostrils and thus in more energy present during

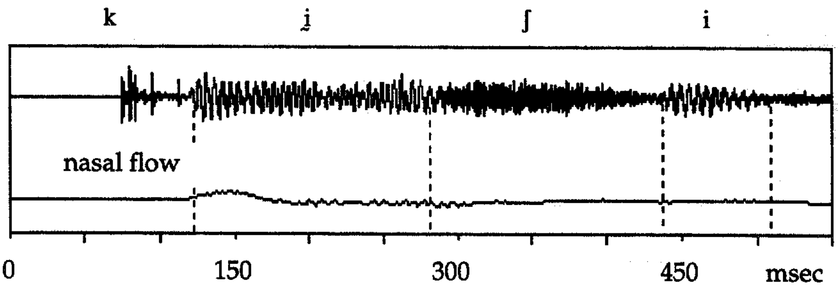

FIG. 5.—Oral [ki̯ʃi] 'come' produced by S1.

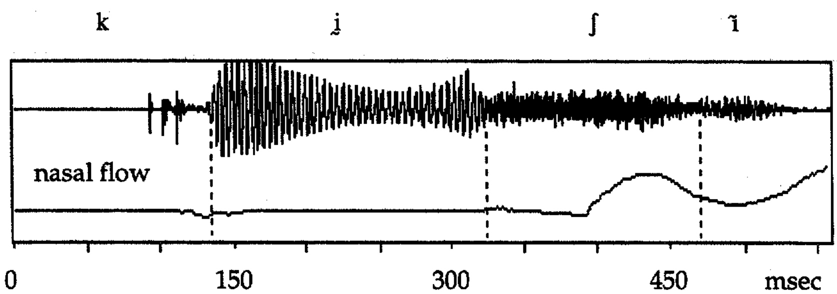

FIG. 6.—Nasalized [ki̯ʃĩ] 'you (FAM) will come' produced by S2.

3.3. The special case of transparent [ʃ]. As noted above, the general pattern of opacity in CM involves the blocking of leftward nasal propagation by a medial voiceless consonant. We have seen that forms such as [ki̯ʃĩ] 'you (FAM) will come' indicate that voiceless fricatives, while blockers of nasalization, can also be realized as phonetically nasalized; i.e., they can be realized with velic aperture during at least part of their production. The fricative [ʃ] is additionally interesting, however, in that there are CM words in which [ʃ] fails to pattern with other voiceless obstruents.

Ultimately, of interest here is that in some forms, [ʃ] can also be transparent to nasalization. The behavior of transparent /ʃ/ is informed by an-

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the fricative than we should expect if the velum were lowered. I do not challenge this observation. However, my own observations of speakers producing 2FAM forms without the nose plugged lead me to conclude that the findings here are accurate in that the voiceless fricatives are audible as fricatives, while at the same time there is often a visible flaring of the nostrils, indicating the presence of a large degree of airflow. Additionally, my impressions are corroborated by Pris Small (p.c.), who has worked with CM speakers for the past 25 years.

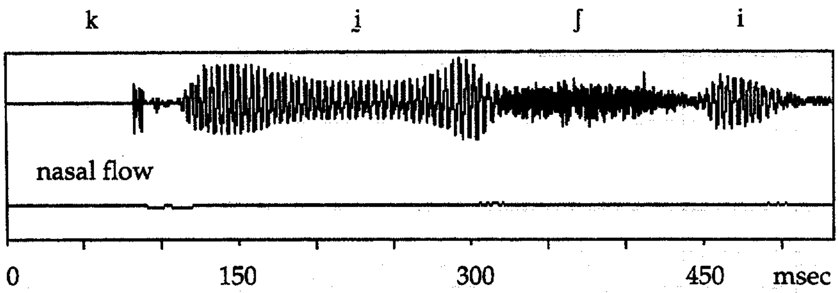

FIG. 7.—Oral [kḭʃi] 'come' produced by S2.

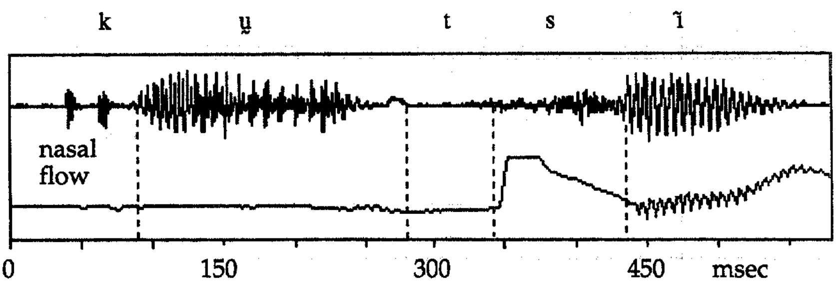

FIG. 8.—Nasalized [kṵtsĩ] 'you (FAM) will bathe' produced by S1.

other aspect of CM phonology: vowel glottalization. Synchronically, CM vowels can be contrastively glottalized in disyllabic couplets if the medial consonant is voiced. Thus, we find minimal pairs such as /uβi/ 'two' versus /ṵβi/ 'pain'. In forms with a medial voiceless consonant, however, glottalization is not contrastive. Specifically, in such forms, V1 surfaces as predictably glottalized, as in [ka̰ka] 'walk'. The lone exception to this generalization is couplets containing a medial [ʃ], which can surface with contrastively glottalized vowels, as seen in minimal pairs such as [ʃɨʃɨ] 'coati' versus [ʃɨ̰ʃɨ] 'mushroom'.

As discussed in Gerfen (1999), the synchronic behavior of CM [ʃ] is best understood in the context of diachrony. Synchronic surface [ʃ] segments have two historical sources: some are derived from the voiced Proto-Mixtec glide */y/, while others are derived from the voiceless Proto-Mixtec velar fricative */x/ (see Josserand 1982). Examples are provided in (4):

(4)	Correspondence	Proto-form	CM	Gloss
	**x > ʃ*	**kixi*	*kḭʃi*	'come'
		**ndixe*	*ndḭʃe*	'true, really'

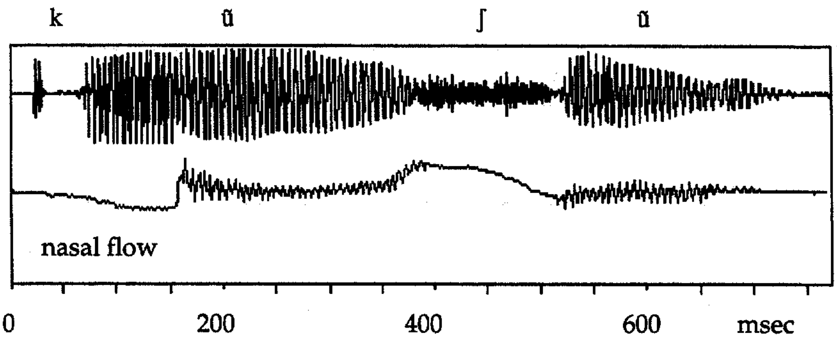

FIG. 9.—Nasalized [kũʃũ] 'you (FAM) are diligent'.

	**ndixĩ*	*ndi̦ʃĩ*	'wing'
*y > ʃ	**yawi*	*ʃaβi*	'hole'
	**yɨyɨ*	*ʃɨʃɨ*	'coati'
	**yuyuʔ*	*ʃuʃu*	'dawn'

Of relevance here is that there are current-day forms containing a medial [ʃ] derived from */y/ that pattern phonologically with voiced obstruents in that they surface with a nonglottalized V1 and are transparent to nasalization. Consider, for example, the nasal flow trace in figure 9 for the form /kuʃu + 2FAM/ 'you (FAM) are diligent', which, for comparison purposes, can be contrasted with its non-nasalized (i.e., non-2FAM) production as /kuʃu/ 'diligent' in figure 10. Both forms are produced by S3.

Of interest in figure 9 is that the trajectory of the nasal flow trace is distinct from what we saw in the case of opaque /ʃ/ above. Rather than exhibiting an abrupt spike in flow corresponding to the onset of velum lowering during the fricative, the trace in figure 9 reflects a gradual decrease in nasal flow throughout the duration of the fricative. Such a pattern might be attributable to a gradual raising of the velum throughout the production of the fricative, to an increased narrowing of the glottis in anticipation of the following vowel, to a declining amplitude pattern over the word as a whole, or to a combination of all three factors. More important, however, such forms strongly confirm the finding for opaque fricatives. That is, fricatives can be (and are in specific contexts in CM) produced with some degree of velic aperture.

4. Conclusions. To what extent, then, do these data falsify the claim that buccal obstruency and velic aperture are universally incompatible? Under its strongest interpretation, Theorem A constitutes an absolute prediction about phonetically possible segments, i.e., about the universal possibilities

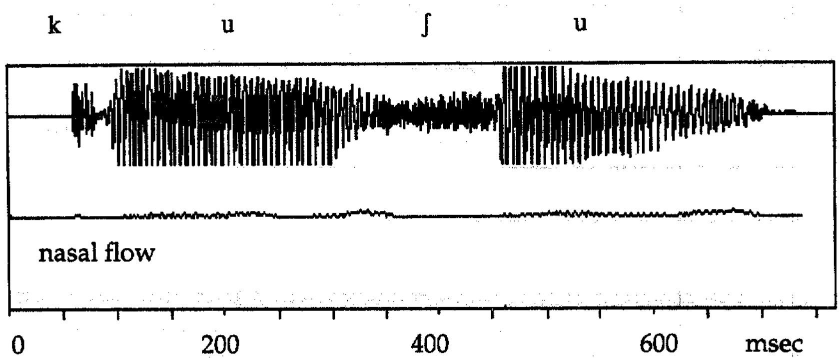

FIG. 10.—Non-nasalized [kuʃu] 'diligent'.

of overlapping articulatory gestures. Thus interpreted, the data counter-exemplify the claim. Taking a different view, however, we might interpret Theorem A to be a statement about the possibilities for contrast in natural language. With this view, the claim remains strong and insightful. Note that nasalized fricatives are not contrastive in CM and that they arise from the anticipation of the morphologically distinctive nasalization of the following vowel.[11] Thus, the locus of contrastive nasality lies not on the voiceless fricative but on the more perceptually salient distinction between oral and nasal vowels.

Does this view fatally weaken the claim? As noted above, nasalized voiceless fricatives are infelicitous sounds. Velum lowering has negative aerodynamic and acoustic consequences for obstruency, while, at the same time, voicelessness is antagonistic to the generation of nasal resonance characteristic of nasal sounds.[12] In phonological terms, nasalized voiceless fricatives require a combination of phonetically ungrounded (see Archangeli and Pulleyblank 1994) features. Theorem A is thus valuable as a markedness statement in that it makes strong predictions about possible linguistic contrasts via a consideration of the physiological and aerodynamic properties of speech production (see Lindblom 1990 and Catford 1977).

Finally, the data call our attention to the importance of language diversity—and in particular of gathering data from underdescribed languages—to the process of testing putatively universal claims. In this case, the CM data indicate that Theorem A cannot be viewed as a universal phonetic

[11] In the data under discussion here, vowel nasalization marks a morphological category, but similar anticipatory velum lowering is also found before contrastively nasalized vowels in forms such as [tsĩĩ] 'fingernail' (see Gerfen 1999).

[12] See Shadle (1997) for discussion of the aerodynamics of fricative production and Fujimora and Erickson (1997) for discussion of the acoustics of voiceless fricatives.

constraint on gestural overlap, given the presence of nasal flow during the production of voiceless fricatives. The data also highlight the necessity of incorporating technology into the task of basic language documentation—technology which can reveal aspects of speech production which are easily missed in manual transcription or which are difficult to verify without instrumental confirmation.

APPENDIX A

Experimental List

[ʃee]	'to arrive'	[tʲɨβi]	'to blow'
[ʃẽ:]	'you (FAM) arrived'	[tʲɨ̃βĩ]	'you (FAM) will blow'
[ðṵ:]	'to rob, steal'	[tʲɨ̰βi]	'to push'
[ðṵ̃:]	'you (FAM) will rob'	[tʲɨ̰̃βĩ]	'you (FAM) will push'
[ðṵku]	'tall'	[kunũ]	'to run'
[ðṵkũ]	'you (FAM) are tall'	[kũnũ]	'you (FAM) will run'
[kṵtʲu]	'to plow, hoe'	[lendʲu]	'dirty'
[kṵtʲũ]	'you (FAM) will plow'	[lẽndʲũ]	'you (FAM) are dirty'
[kḭʃi]	'to come'	[lṵndi]	'small'
[kḭʃĩ]	'you (FAM) will come'	[lṵ̃ndĩ]	'you (FAM) are small'
[kṵtsi]	'to bathe'	[kuʃu]	'diligent'
[kṵtsĩ]	'you (FAM) will bathe'	[kũʃũ]	'you (FAM) are diligent'
[kiði]	'to sleep'	[tsi:]	'to get wet'
[kĩðĩ]	'you (FAM) will sleep'	[tsĩ:]	'you (FAM) will get wet'
[βiðe]	'wet'	[tsĩ:]	'fingernail'
[βĩðẽ]	'you (FAM) are wet'	[βĩðĩ]	'sweet'
[kuβi]	'to die'	[tʲṵtũ]	'firewood'
[kũβĩ]	'you (FAM) will die'		

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