AN ACOUSTIC STUDY OF PLAIN AND PALATALIZED SIBILANTS IN OCOTEPEC MIXE

Silke Hamann & Heriberto Avelino

Utrecht University & UC Berkeley / Stanford University
silke.hamann@let.uu.nl & avelino@berkeley.edu

ABSTRACT

In Ocotepec Mixe, the stem-initial sibilants /s t͡s ʂ/ undergo a palatalization process when the prefix /j/ is added. Descriptions of other Mixe languages report that this palatalization is realized either as addition of a glide (in the case of the alveolar and retroflex sibilants) or as a change in the primary place of articulation (in the case of the affricate). The acoustic measurements in the present study indicate that all palatalized sibilants in Ocotepec have an additional glide, unless they are followed by the high front vowel(s) /i (e)/, and that both the affricate and retroflex fricative show a consistent change in primary place of articulation under palatalization.

Keywords: Mixe, acoustics, palatalization, sibilants, retroflex.

1. INTRODUCTION

Santa Maria Ocotepec is a Mixe-Zoquean language spoken in Northeastern Oaxaca, in the district of Totontepec Villa de Morelos. Like other Mixe languages (cf. [5]), Ocotepec has a third person marker /j/, which is prefixed to the stem of a word. This morpheme is usually realized as secondary palatalization of the stem-initial consonant, see the example in (1a).

(1) a) [kaːn] 'salt' [kʲaːn] 'his/her salt'
b) [t͡sim] 'gourd' [t͡ʃim] 'his/her gourd'

For the alveolar affricate /t͡s/, affixation of /j/ triggers a change in the primary place of articulation towards the postalveolar [t͡ʃ], as illustrated with the example in (1b).

Besides /t͡s/, Ocotepec has two further sibilants, the native retroflex /ʂ/, and the Spanish loan sibilant /s/, see the overview in Table 1.

Table 1: Sibilants of Ocotepec Mixe.

plain	palatalized
t͡s	t͡ʃ
s	sʲ
ʂ	ʂʲ

Both also undergo palatalization when the prefix /j/ is added. Mixe palatalized /s/ is usually described as sequence of plain sibilant and short glide, i.e. as exhibiting secondary palatalization. For the post-alveolar fricative the descriptions differ. In Isthmus Mixe, spoken in Eastern Oaxaca (in the vicinity of Guichicovi), the corresponding segment is realized as laminal postalveolar [ʃ], which exhibits secondary palatalization (see the phonetic study by Dieterman [4]). In Totontepec Mixe, a close neighbour of Ocotepec, however, the postalveolar is realized as [ʂ], and Crawford [3] describes it as having a "somewhat fronted and not retroflexed variant" (p.42) when palatalized. This is in line with Hamann's [8] claim that retroflex consonants are de-retroflexed when palatalized because of the opposing tongue gestures involved in retroflexion and palatalization.

In the present study we compare the acoustic characteristics of the plain and palatalized sibilants in Ocotepec Mixe. In doing so, we determine whether the place of articulation for the retroflex sibilant in Ocotepec changes under palatalization. In addition, we test whether only the alveolar and retroflex sibilants in Ocotepec are realized with an additional glide when palatalized and the alveolar fricative is not, as described for Totontepec Mixe ([3]) and Ishthmus Mixe ([4]).

2. ACOUSTIC ANALYSIS

We recorded one male and two female adult native speakers of Mixe in the field. The recordings were made on a portable analogue tape recorder and were digitized at 22,050 Hz.

For the sibilants /s/ and /t͡s/ and their palatalized counterparts we recorded six words each, and for the /ʂ/ and its palatalized counterpart four words, all given in the Appendix. The words were produced in isolation and were repeated three times.

Segmentation and labelling of the target sibilants was done manually based on spectrogram and waveform. Acoustic measurements of the following parameters were performed by using

PRAAT [1]. We measured the duration of the target sibilants from beginning to end of the frication noise. Furthermore, we measured the duration of a following glide if present. The cessation of sibilant friction noise was considered the starting point of the glide, and its endpoint was determined on the basis of the intensity of the signal (an increase of intensity for the following vowel) and the course of the first three formants.

In addition, we measured centre of gravity values for the whole duration of the sibilant tokens, excluding the first and last 10 percent of each token. The centre of gravity was calculated by weighting the frequencies in the spectrum by their power densities (see e.g. Forrest et al. [6]). Before applying this measure, we filtered the signal to exclude the region below 900 Hz.

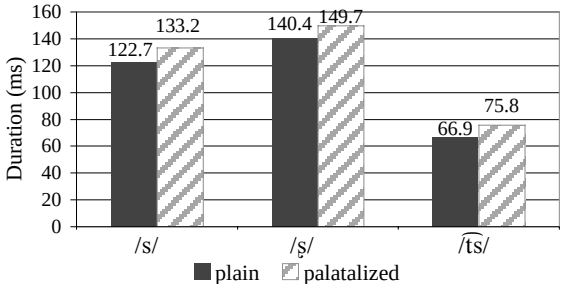
3. RESULTS

In the following analyses we included 285 tokens, 144 contained a plain and 141 a palatalized sibilant. We had 75 tokens with /ʂ/, 102 with /s/, and 107 with /t͡s/.

3.1. Duration of sibilants

A two-factor ANOVA (fricative and palatalization) pooled over the three speakers showed a significant effect of both fricative and palatalization on duration measurements (fricative: $F(2, 283)=326.983$, $p<0.001$; palatalization: $F(1, 284)=14.781$, $p<0.001$). The retroflex sibilant showed the longest and the sibilant part of the alveolar affricate the shortest duration. Though the palatalized sibilants all show longer durations than their plain counterparts, cf. Figure 1, the differences within sibilant pairs are not significant.

Figure 1: The mean duration values for the Ocotepec plain and palatalized sibilants.



Our findings on the short affricate friction are in accordance with earlier studies, where the friction part of an affricate was reported to be shorter than that of a fricative, see e.g. Castleman & Diehl [2] on American English.

Consistent durational difference such as those we found between alveolar and retroflex fricatives have not been reported in the literature. In Gordon et al.'s study [7], five of the six Tamil subjects showed a longer duration for the retroflex /ʂ/ than for the alveolar /s/, but one subject displays the reverse pattern.

3.2. Presence of glides

We found that none of the 144 tokens with plain sibilants has a glide, in accordance with the expectations. For the 141 tokens with palatalized sibilants, 104 had a glide (72.2 %). The remaining 37 palatalized tokens consisted of all tokens of /t͡ʃi/ and /t͡ʃe/ (eighteen in total). Furthermore, all eighteen tokens of /sʲi/ and one token of /ʂʲu/ belonged to this group.

We can conclude that the palatalized affricate in Ocotepec is realized with a glide, unless followed by /i/ or /e/. This is in contrast to what has been described for other Mixe languages ([3, 4]), where the palatalized affricate does not surface with a glide.

In our data, an avoidance of derived /ʲi/ could not only be observed after /t͡ʃ/, but also after /s/ (/sʲe/, however, did occur). We cannot state whether /ʂʲi/ and /ʂʲe/ are also avoided, because we did not include any words with retroflex sibilants followed by /i/ or /e/ in our experiment. An avoidance of palatal glide plus high front vowel is cross-linguistically quite common and usually ascribed to the acoustic and perceptual similarity between the two segments ([9]). A further explanation might be the articulatory effort involved in the production of /ʲi/ sequences, where the glide has to be articulated with a higher and more fronted tongue position than usually (see Laver [10, p. 298] on English and the Chentu dialect of Chinese).

The glides following the palatalized sibilants do not differ significantly in their duration.

3.3. Centre of gravity

The centre of gravity (or: spectral mean) correlates with the size of the front cavity, and is lower for postalveolar articulations and higher for alveolar ones. We therefore expected the Ocotepec retroflex sibilant to have lower spectral mean values than any other sibilants in this language.

Our measurements are given in Figure 2, where we present the data for the three subjects separately, due to large inter-speaker variation.

Figure 2: Spectral mean values for the Ocotepec plain and palatalized sibilants, for speakers one, two (both female), and three (male).

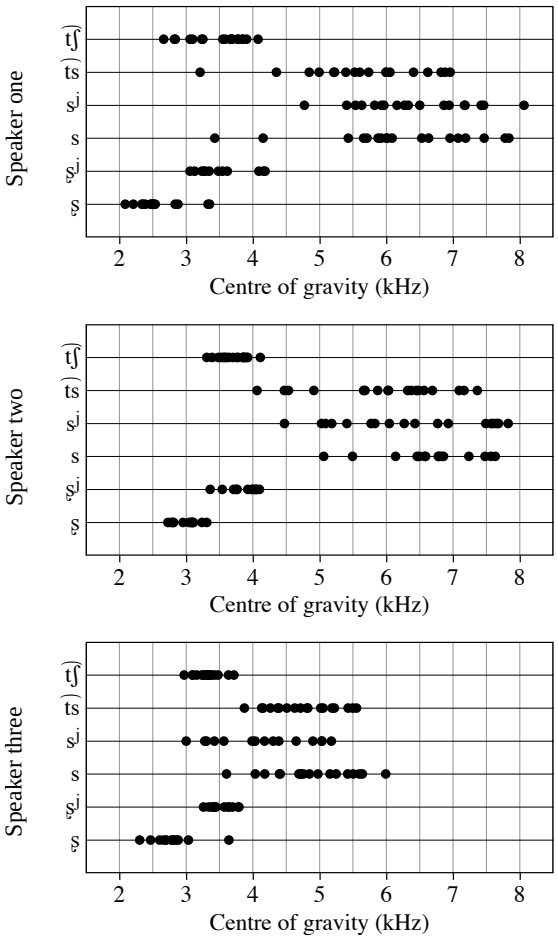
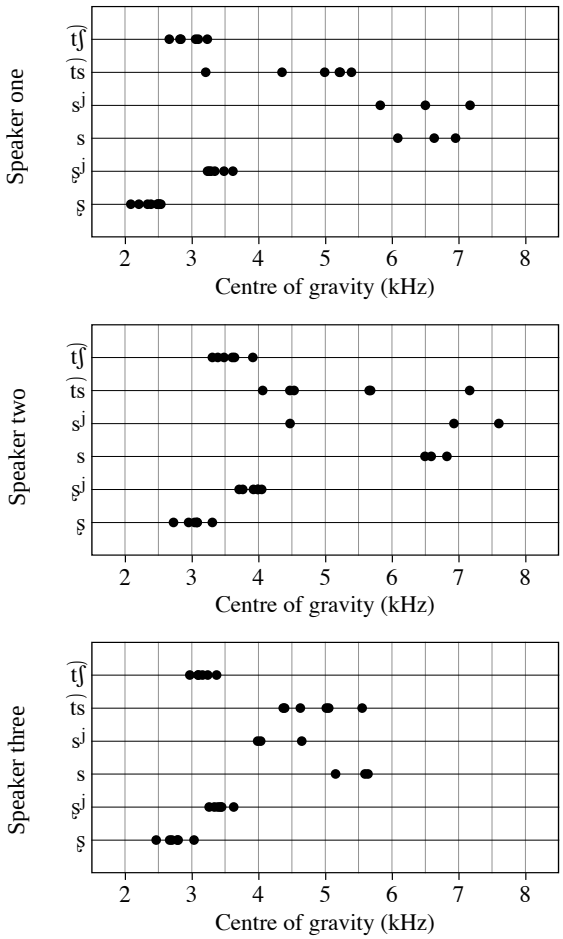


Figure 3: Spectral mean values for the Ocotepec sibilants followed by the vowel /o/, for the same three speakers as in Figure 2.



The plain retroflex tokens have indeed lowest values for all three speakers, as expected. The spectral mean values for the palatalized retroflex tokens, however, are higher than those for the plain retroflex ones (on average 0.85 kHz). They almost totally overlap with the values for the palatalized affricate /t͡ʃ/ (the latter are on average 0.14 kHz lower). This overlap is a clear indication that the phonologically palatalized retroflex is not realized as retroflex but as laminal postalveolar or alveolo-palatal (the small average difference between /t͡ʃ/ and /ʂʲ/ might be interpreted as the realisations of the fricative parts as [ʃ$^{(j)}$] and [ɕ], respectively, compare the difference in centre of gravity values for the same surface sounds in Polish measured by Zygis & Hamann [11]).

The values for the palatalized affricate tokens are lower and very distinct from the values for the fricative part of the plain affricate tokens. This supports the postalveolar status of the palatalized affricate, in accordance with the literature.

The tokens of alveolar /t͡s/, /s/ and /sʲ/ have highest centre of gravity values. They overlap largely with each other and are scattered over an area of 2 – 3.5 kHz.

In the present study, we did not control for vowel quality, and as a consequence, the sibilants are followed by different sets of vowels. Only the back mid /o/ occurred after every sibilant. To exclude a possible influence of the different vowel contexts, we additionally looked at the spectral mean values for sibilants followed by /o/, only. These values, as presented in Figure 3, do not yield any additional findings, but confirm the ranking of sibilants in (2) that emerged from Figure 2 (where "<" stands for "has a lower spectral mean than"):

(2) /ʂ/ < { /t͡ʃ/, /ʂʲ/ } < { /t͡s/, /s/, /sʲ/ }

A disambiguation of categories with overlapping centre of gravity values (in curly brackets) is probably performed with additional parameters such as stop closure and formant transitions.

4. DISCUSSION

The present study compared the acoustic characteristics of plain and palatalized sibilants (two fricatives and one affricate) of Santa Maria Ocotepec Mixe and checked whether these sounds are realized in the same way as corresponding sibilants in neighbouring Mixe languages.

We found that in Ocotepec all three palatalized sibilants are realized with a palatal glide, in contrast to reports on other Mixe languages, where only the two palatalized fricatives have a glide. In our data, the glide did not surface with a following /i/ (for affricate and alveolar fricative) or /e/ (for the affricate, only). Such restrictions on sequences of palatal glide and front vowels were not reported before in Mixe, but are quite common cross-linguistically.

Furthermore, we found that both the affricate and the retroflex fricative show a change in place of articulation when palatalized. The palatalized affricate is realized as postalveolar, as is common for Mixe languages. The so-called palatalized retroflex sibilant was shown to have a similar centre of gravity than the friction phase of the palatalized affricate, indicating a laminal post-alveolar articulation. This observation is in accordance with what has been reported for the neighbouring language Totontepec by Crawford [3], and with the general claim by Hamann [8] that palatalization and retroflexion are articulatorily incompatible.

On the basis of our findings, the sibilant system of Ocotepec in Table 1 has to be revised as follows:

Table 2: Sibilants of Ocotepec Mixe (revised).

plain	palatalized	non-occurring
t͡s	t͡ʃʲ	t͡ʃʲi, t͡ʃʲe
s	sʲ	sʲi
ʂ	ʃʲ / ɕʲ	(? ʃʲi)

The (non)existence of [ʃʲi] sequences can only be determined on the basis of further recordings. In addition, future articulatory studies need to clarify the exact realization of the sibilants in Ocotepec, specifically of the palatalized "retroflex" sibilant.

5. ACKNOWLEDGEMENTS

We would like to thank our subjects Federica Diaz, Engracia Perez, and Rodrigo Vazquez, as well as Paul Boersma for technical advice. This study was made possible by a UC Berkeley grant to Heriberto Avelino and a NWO grant to Silke Hamann.

6. APPENDIX

In the orthographic representations of the Ocotepec words below we used the following transcriptional conventions: *ë* = [ə], *ch* = [tʃ], *x* = [ʂ], *y* = [j], and *'* = [ʔ]. Note that the words with initial /s/ are all loanwords from Spanish.

serbesa – syerbesa	'(his/her) beer'
seboya – syeboya	'(his/her) onion'
sopa – syopa	'(his/her) soup'
silantro – syilantro	'(his/her) coriander'
siruela – syiruela	'(his/her) plum'
sueter – syueter	'(his/her) sweater'
tsokën – chokën	'(his/her) ant'
tsoo' - choo'	'(his/her) sapote (fruit)'
tseeb- cheeb	'(his/her) chicken'
tsim- chim	'(his/her) gourd'
tsaam- chyaam	'(his/her) banana'
tsëkën – chyëkën	'(his/her) remains'
xaaxt – xyaaxt	'(his/her) larynx'
xuum – xyuum	'(his/her) net'
xooxën – xyooxën	'(his/her) wind instrument'
xookx – xyookx	'(his/her) colibri'

7. REFERENCES

[1] Boersma, P, Weenink, D. 2006. *Praat: doing phonetics by computer* (Version 4.5.08) [Computer program]. Retrieved December 20, 2006, from http: //www.praat.org/

[2] Castleman, W.E., Diehl, R.L. 1996. Acoustic correlates of fricatives and affricates. *J. Acoust. Soc. Am.* 99, 2546.

[3] Crawford, J.C. 1963. *Totontepec Mixe phonotagmemics*. Dallas: SIL.

[4] Dieterman, J. I. 2002. *Secondary palatalization in Isthmus Mixe: A phonetic and phonological account*. Ph.D. dissertation, University of Texas, Arlington.

[5] Elson, B. F. 1992. Reconstructing Mixe-Zoque. In: Hwang, S., Merrifield, W. (eds.) *Language in context: Essays for Robert Longacre*. Dallas: SIL, 577-592.

[6] Forrest, K., Weismer, G., Milenkovic, P., Dougall, R. N. 1988. Statistical analysis of word-initial voiceless obstruents: Preliminary data. *J. Acoust. Soc. Am.* 84, 115–124.

[7] Gordon, M., Barthmaier, P., Sands, K. 2002. A cross-linguistic acoustic study of voiceless fricatives. *Journal of the International Phonetic Association* 32, 141-174.

[8] Hamann, S. 2003. *The phonetics and phonology of retroflexes*. Utrecht: LOT Publications.

[9] Kawasaki, H. 1982. *An Acoustical Basis for Universal Constraints on Sound Sequences.* Ph.D. dissertation, University of California, Berkeley.

[10] Laver, J. 1994. *Principles of Phonetics.* Cambridge: Cambridge University Press.

[11] Zygis, M., Hamann, S. 2003. Perceptual and acoustic cues of Polish coronal fricatives. *Proc. 15th ICPhS* Barcelona, 395-398.