Indiana University

Phasing and Recoverability: Laryngeal Complexity in Otomanguean Vowels

Daniel Silverman
daniel@cogsci.uiuc.edu

Introduction

1. The timing ("phasing") patterns among articulatory gestures typically optimize the salience acoustic cues, maximizing recoverability

   {coronal stop, laryngeal abduction} ⇨ **tʰ** (Kingston 1985, 1990)

2. Contrastive phasing patterns are normally maximally distinct from one another

   {coronal stop, laryngeal abduction} ⇨ **tʰ** and **ʰt** (Silverman 1995, 1997)

3. The presence of a sub-optimal phasing pattern usually implies the presence of the optimal phasing pattern

   {coronal stop, laryngeal abduction} **tʰ** >> **ʰt** (Silverman 1995, 1997)

4. Today's inquiry: "laryngeally complex vowels"

   {vowel, laryngeal abduction, tone} **ha˥** >> **ah˥** >> **aha**
   {vowel, laryngeal constriction, tone} **ʔa˥** >> **aʔ˥** >> **aʔa˥**

laryngeally *simplex* class:

5. Neither contrastive tone nor contrastive phonation
   plain vowel (e.g., English): **a**

6. Contrastive tone, but no contrastive phonation
   toned vowel (Mandarin, Maddieson 1984): **a˥**
7. Contrastive phonation, but no contrastive tone
   breathy vowel (Gujarati,Fischer-Jørgensen, 1970): **a̤**
   creaky vowel (Sedang, Smith 1968): **a̰**

8. <u>White Hmong</u> (Lyman 1974, Smalley 1976, Huffman 1987, Ratliff 1992):

High	**tau**^{55}	pumpkin
Rising	**tau**^{35}	to dam up (water)
Low	**tau**^{22}	axe
Mid (normal)	**tau**^{33}	to be able
Falling (normal)	**tau**^{42}	sp. of grass
"Creaky"	**tau**^{31}	bean
"Breathy"	**tau**^{32}	to follow

Ratliff: For male speakers, the breathy tone is implemented as a low, whispered pitch fall: **V̤**^{31}; For female speakers, the breathy tone is implemented as a high, whispered fall: **V̤**^{53}. Pitch is thus not the primary cue to the contrast.

Laryngeal Complexity in Otomanguean Vowels

10. Layngeal complex vowels:

{**V**, **h**/**ʔ**, ˥}	<u>Jalapa Mazatec</u>:		<u>Comaltepec Chinantec</u>:		<u>Copala Trique</u>:	
	abduction:	constriction:	abduction:	constriction:	abduction:	constriction:
optimal	**ha˥**	**ʔa˥**	**ha˥**	**ʔa˥**	**ha˥** **-loans only-**	**ʔa˥**
maximally distinct	**ah**	**aʔ˥**	**ah˥**	**aʔ˥**	**ah˥**	**aʔ˥**
again maximally distinct	**aha˥**	**aʔa˥**	**aha˥**	**aʔa˥**	**aha˥**	**aʔa˥**

10. **Jalapa Mazatec** (Pike and Pike 1947, Kirk 1966, Bull 1983, 1984, Steriade 1992, Silverman 1994a, Kirk, Ladefoged, and Ladefoged 1993, Silverman, Blankenship, Kirk, and Ladefoged 1995):

<u>Jalapa Mazatec segment inventory</u> (Silverman, Blankenship, Kirk, and Ladefoged 1995):

(p)	**t**	**ts**	**tʃ**	**k**	**i**	**u**
(pʰ)	**tʰ**	**tsʰ**	**tʃʰ**	**kʰ**		**o**
(ᵐb)	**ⁿd**	**ⁿdz**	**ⁿdʒ**	**ᵑg**	**æ**	**a**
	s		**ʃ**			
m	**n**		**ɲ**	**ŋ**		
	(l)					
w		**j**				

h,ʔ

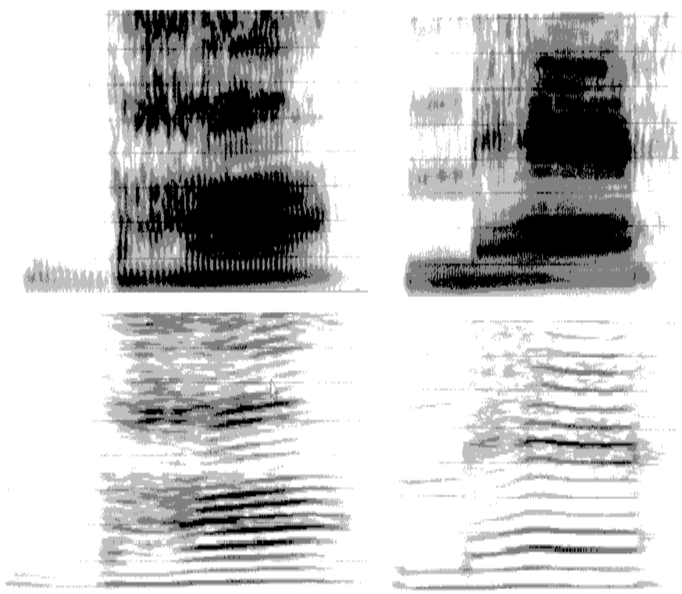
(parenthesized segments are limited to loanwords)

20. tones (Kirk 1966): **H**, **M**, **L**, **LM**, **LH**, **ML**, **MH**, **HL**, **HM**, **LML**, **LHL**, **MHL**

21.

toned breathy vowel:		toned creaky vowel:	
mm̤æ̤͡æː˦˥	wants	**mm̰o̰͡o˧sḛ͡e˧**	eviction
nn̤a̤͡a˦˥	my tongue	**nn̰æ̰͡æ˧**	he says
ɲɲ̤a̤͡a˧	nine	**ɲɲ̰V̰͡V**	(unattested)
ʝʝæ̤͡æ˩	boil	**ww̰a̰͡aj˧tsẽːj˧**	he remembers
ww̤o̤͡o˧	hungry	**ti˥ww̰ḛ͡e˧**	hits, gives birth to

22. Spectrograms of laryngeally complex vowels in Jalapa Mazatec:



mm̤æ̤͡æ˦˥ hard

nda̤͡a˦˥ he wants

23. summary:

{**V**, **h**/**ʔ**, ˥}	Jalapa Mazatec:	
	abduction:	constriction:
optimal	**ha˥**	**ʔa˥**
maximally distinct	**ah**	**aʔ˥**

again maximally distinct	**aha˥**	**aʔa˥**

24. **Comaltepec Chinantec** (Anderson 1989, 1990, Anderson, Martinez, and Pace 1990, Silverman 1994a,b, 1995):

Comaltepec segment inventory:

p	**t**	**tʃ**		**k**	**i**	**ɨ**	**u**
ᵐb	**ⁿd**	**ⁿdʒ**		**ᵑg**	**e**	**ʌ**	**o**
(f)	**s**	**(ʃ)**	**(ʂ)**	**(x)**	**æ**		**a**
			ʐ				
m	**n**			**ŋ**			
	l						
		j		**w**			

h,ʔ

(Parenthesized forms are major allophonic or free variants)

25. tones:

L	**hi˩**	book
H	**l̥loʔ˥**	pretty
M	**ⁿdʒœː˧**	earthen jar
LM	**ᵑgiŋʔ˩˧**	swing
LH	**li˩˥**	tepejilote palm shoot

26. laryngeals:

hi˩	book	**ʔoː˧**	papaya

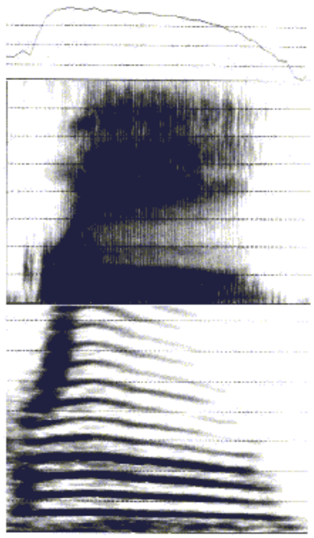
27. toned vowels: / toned with post-vocalic aspiration:

toned vowels		toned with post-vocalic aspiration	
ᵑgwoː˩	good (i)	**ᵑgjʌŋ̊˧**	hand
heʔ˩˧	frog	**lih˥**	flower

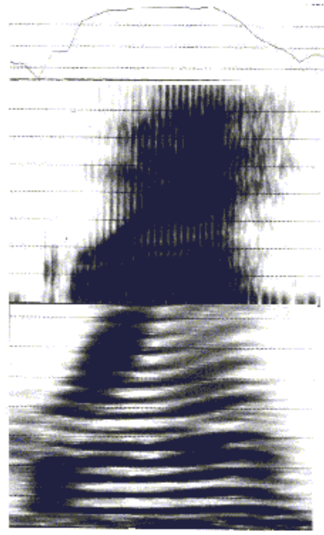
28. "Ballistic syllables"; syllables with post-vocalic aspiration--consequences for subglottal pressure and pitch:

gestures:	primary gesture:		secondary gesture:
articulatory:	laryngeal abduction		increased internal intercostal activity
consequences:	⇘		⇙
aerodynamic:		increased subglottal pressure	
		⇩	
		increased transglottal airflow	
		⇩	
articulatory:		increased vocal fold vibration	
		⇩	
acoustic:		increased F0, increased amplitude of noise	
		⇩	
auditory:		increased pitch, increased loudness	
		⇩	
perceptual:		increased salience	

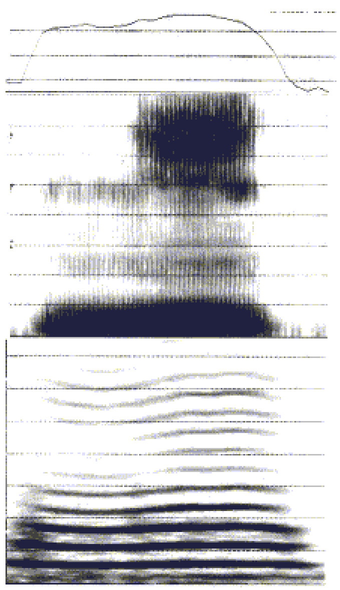
29. <u>Spectrograms of controlled and ballistic syllables in Comaltepec Chinantec</u>:



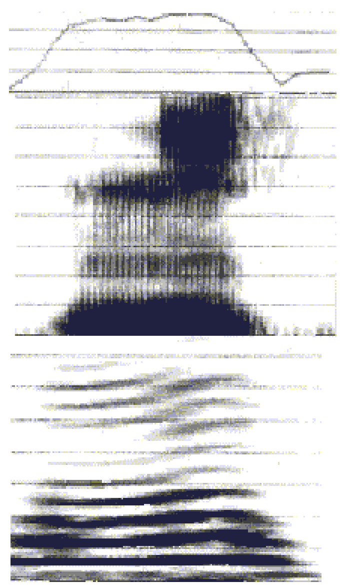
kweː˧
long



(mɨ˧) kweːh
arm



ni˥
face



niːh˦
sit!

30. summary:

{**V**, **h**/**ʔ**, ˥}	Jalapa Mazatec:		Comaltepec Chinantec:	
	abduction:	constriction:	abduction:	constriction:
optimal	**ha˥**	**ʔa˥**	**ha˥**	**ʔa˥**
maximally distinct	**ah**	**aʔ˥**	**ah˥**	**aʔ˥**
again maximally distinct	**aha˥**	**aʔa˥**	**aha˥**	**aʔa˥**

31. **Trique (**Longacre 1952, 1957, 1959, Hollenbach 1978):

San Juan Copala Trique segment inventory:

(**p**)	**t**				**k**	**i**		**ɨ**		**u**
(**b**)	**d**				**g**		**e**		**o**	
		tʃ	**cç**	**ʈʂ**				**a**		
	s	**ʃ**		**ʂ**						
	z	**ʒ**								
				ɾ						
m	**n**									
	l									
			j		**w**					

ʔ, **h**

(parenthesized segments are limited to loanwords)

32. tones: **21**, **32**, **3**, **34**, **35**, **4**, **5**, **53** (where **1** is highest, **5** is lowest)

33. laryngeals may precede the toned vowel.

		-loans only-	
ʔũ	nine	**a^{2}hu^3**	garlic
ʔu^{5}ʔuˑ^5	five	**hu^{3}lja^3**	Julia
ʔweʔe^5	ice, frost	**gaw̥we^{32}**	coffee
ʔnɨh^5	inside of		

34. Only the laryngeals (**ʔ** and **h**) may close syllables, and only final syllables may be closed.

waʔ^{5}	the right	**ʒu^{2}kwah^{1}**	to be twisted
jaʔ^{34}	teeth	**jah^{3}**	ashes
ni^{5}kaʔ^{5}	short	**ɾah^{21}**	to grind

35. Open final syllables are long

ma^{4}ɾeː^{3}	red
gu^{3}naː^{23}	to remain
ɾa^{3}ʔaː^{3}	hand
ɾi^{3}oː^{43}	trough, manger

36. Final vowels may be laryngeally "interrupted," in which **h** or **ʔ** intrude on the vowel (i.e., **VhV**, **VʔV**).

ga^{3}tu^{4}ʔu^{3}	incense-burner
ri^{3}u^{5}hu^{3}	hollow reed
na^{3}ʔa^{4}ha^{3}	conversation

37. Six reasons to interpret interrupted vowels as laryngeal gestures phased to interrupt a single vocalic gesture, rather than one involving two distinct vowel gestures

a. Interrupted forms do not undergo final lengthening

<u>interrupted vowel</u>:		<u>true **V-ʔ-V** sequence</u>:	
we^{3}ʔe^{3}	house	**we^{3}ʔeː^{2}**	beautiful
ja^{3}ha^{3}	flower	**da^{3}ʔaː^{34}**	cord, root
na^{3}ki^{4}hi^{3}	atole	**ʔu^{5}ʔuː^{5}**	five
jo^{3}ʔo^{3}	year	**jo^{3}ʔoː^{53}**	the gummy deposit made by smoke from a wood fire

b. Interrupted forms lose their second vocalic component in phrasal contexts

ja^{3}ha^{3}	but	**ja^{3}h zi^{3}ŋa^{2}**	nasturtiums
jo^{3}ʔo^{3}	but	**jo^{3}ʔ ga^{3}ci^{23}**	the past year
naki^{4}hi^{3}	but	**naki^{4}h ru^{4}ne^{43}**	bean-atole

This elision is not reported for true **V-ʔ-V** sequences

c. Interrupted vowels often appear in otherwise canonical bisyllabic words, whereas true trisyllabic words are quite rare

na^{4}ki^{3}hi^{3}	atole	**ga^{3}u^{4}ʔu^{3}**	incense burner
gi^{3}ʔja^{4}ha^{3}	holy day, festival	**ɾe^{3}ka^{4}ʔa^{3}**	stick
na^{2}nɨ^{5}hɨ^{4}	open	**ɾe^{3}ke^{4}ʔe^{3}**	splinter

da³ku⁵hu⁴ ascent

d. Tonal sequences occurring on interrupted forms are limited to those which occur on single vowels

e. Voiceless obstruents and "fortis" nasal consonants may occur before interrupted sequences. Elsewhere, these consonants are limited to word-final syllables. If interrupted vowels are single nuclei, then a strong generalization may be made regarding the distribution of voiceless and fortis consonants: they are limited to final syllables.

f. Interrupted vowels always possess but a single vowel quality, whereas true sequences may possess two vowel qualities (reported in Longacre 1957, no examples given)

38. summary:

{**V**, **h**/**ʔ**, ˥}	Jalapa Mazatec:		Comaltepec Chinantec:		Copala Trique:	
	abduction:	constriction:	abduction:	constriction:	abduction:	constriction:
optimal	**ha˥**	**ʔa˥**	**ha˥**	**ʔa˥**	**ha˥** **-loans only-**	**ʔa˥**
maximally distinct	**ah**	**aʔ˥**	**ah˥**	**aʔ˥**	**ah˥**	**aʔ˥**
again maximally distinct	**aha˥**	**aʔa˥**	**aha˥**	**aʔa˥**	**aha˥**	**aʔa˥**

---

10. Question: What might be the acoustic and articulatory consequences of implementing a laryngeally complex vowel?

Sufficient acoustic discriminibility

11. **Acoustics of laryngeally complex vowels:**

a. Toned vowels: F0 may be recovered from the pulse period the frequency range between 400 and 1000 Hz. is the most important for pitch perception (Ritsma 1967, Remez and Rubin 1984, 1993).		b. Breathy vowels: The acoustic signal possesses harmonics and noise, with weakening of harmonics above H1, and increased bandwidth of surviving harmonics Kirk, Ladefoged, and Ladefoged (1993:445): "The breathy vowel [in Jalapa Mazatec] is characterized by an onset of indiscernible pulses."		c. Creaky vowels: when a pulse period varies, or jitters, by more than 10%, a stable pitch is not reliably discernible (Rosenberg 1966 Cardozo and Ritsma 1968)
Toned Vowel		Breathy Toned Vowel		Creaky Toned Vowel

Formant	Harmonic	Frequency
	...	**...**
	H9	**1125**
	H8	**1000**
	H7	**875**
	H6	**750**
	H5	**625**
F1	**H4**	**500**
	H3	**375**
	H2	**250**
	H1	**125**

Formant	Harmonic	Frequency
	...	...
	H9	1125⇳
	H8	1000⇳
	H7	875⇳
	H6	750⇳
	H5	625⇳
F1	H4	500⇳
	H3	375⇳
	H2	250⇳
	H1	**125⇳**

Formant	Harmonic	Frequency
	...	**...**
	H9	**1125↑↓↑↓**
	H8	**1000↑↓↑↓**
	H7	**875↑↓↑↓**
	H6	**750↑↓↑↓**
	H5	**500↑↓↑↓**
F1	**H4**	**375↑↓↑↓**
	H3	**375↑↓↑↓**
	H2	**250↑↓↑↓**
	H1	125↑↓↑↓

12. Languages which possess both contrastive tone and contrastive non-modal phonation (breathiness/creakiness) such as Mazatec, Chinantec, and Trique, may sequence their tonal and non-modal phonatory gestures, so that both tone and phonation are recoverable.

13. **<u>Articulation of laryngeally complex vowels</u>**:

Sufficient Articulatory Compatability

tone with breathy phonation

	V̤˥	V̤˩
vocal fold tension:	higher: ✓	higher:
	lower: ✓	lower: ✓
glottal aperture:	higher: ✓	higher: ✓
	lower:	lower: ✓
intercostal flexion:	higher: ✓	higher: ✓
	lower:	lower: ✓
larynx height:	higher: ✓	higher:
	lower: ✓	lower: ✓

14. <u>summary</u>:
attempting to reach a particular pitch target and a breathy target simultaneously involves conflicting articulatory demands

15. Tone with creaky phonation:

	V̰˥	V̰˩
vocal fold tension:	higher: ✓	higher: ✓
	lower:	lower ✓
glottal aperture:	higher: ✓	higher:
	lower: ✓	lower: ✓
intercostal flexion:	higher: ✓	higher: ✓
	lower:	lower: ✓
larynx height:	higher: ✓	higher: ✓
	lower:	lower: ✓

16. <u>summary</u>: Attempting to reach a particular pitch target and a creaky target simultaneously involves conflicting articulatory demands

17. <u>Question</u>: given these acoustic and articulatory incompatibilities, what are the consquences for laryngeally complex vowels?

42. <u>Auditory phonetics (Bladon 1986)</u>:

a. **<u>On/off response asymmetry</u>**: spectral changes whose response in the auditory nerve is predominantly an onset of firing are much more perceptually salient than those producing an offset (Tyler, Summerfield, Wood, and Fernandes 1982).

CV >> **VC**

b. **<u>Short-term adaptation</u>**: after a rapid onset of auditory nerve discharge at a particular frequency, there is a decay to a moderate level of discharge, even though the same speech sound is continuing to be produced (Delgutte 1982).

V >> **Vː** >>> **Vːː**

43. <u>generalization</u>: acoustic signals that involve *abrupt increases in acoustic energy* trigger maximal auditory nerve response

58. **Conclusions:**

- A functional link may be established between recoverability and markedness
- In laryngeally complex vowels, tone and phonation are phased away from each other, so that all contrasts are recoverable
- The more contrastive phasing patterns added, the more marked (the less recoverable) the added patterns are, but they remain optimally distinct from each other

References

Anderson, J.L. (1989) *Comaltepec Chinantec Syntax*. Studies in Chinantec Languages v. 3. Summer Institute of Linguistics.

Anderson, J.L., I.H. Martinez, and W. Pace (1990) "Comaltepec Chinantec Tone," in W.R. Merrifield and C.R. Rensch, eds., *Syllables, Tone, and Verb Paradigms.* Studies in Chinantec Languages v.4. Summer Institute of Linguistics, 3-20.

Bauernschmidt, A. (1965) "Amuzgo Syllable Dynamics," Language 41.3:471-483.

Bickley, C. (1982) "Acoustic Analysis and Perception of Breathy Vowels," MIT Speech Communication Working Papers 1:73-83.

Bladon, A. (1986) "Phonetics for Hearers," in G. McGregor, ed., *Language for Hearers*. Oxford : Pergamon Press, 1-24.

Blankenship, B., P. Ladefoged, P. Bhaskararao
, and N. Chase (1993) "Phonetic Structures of Khonoma Angami," Linguistics of the Tibeto-Burman Area 16.2:69-88.

Browman, C.P., and L. Goldstein (1986) "Towards an Articulatory Phonology," Phonology Yearbook 3:219-252.

Browman, C.P., and L. Goldstein (1989) "Articulatory Gestures as Phonological Units," Phonology 6:201-251.

Browman and Goldstein (1990a) "Gestural Specification Using Dynamically-Defined Articulatory Structures," Journal of Phonetics 18:299-320.

Browman, C.P. and L. Goldstein (1990b) "Tiers in Articulatory Phonology, with some Implications for Casual Speech," in J. Kingston and M.E. Beckman, eds., *Papers in Laboratory Phonology I: Between the Grammar and the Physics of Speech*. Cambridge University Press, 341-376.

Browman C.P., and L. Goldstein (1992) "Response to Commentaries," Phonetica 49:222-234.

Bull, B.E. (1983) "Constraint-Governed Rule Application: Principles Underlying the Application of Phonological Rules in San Jerónimo Mazatec. Linguistics 21:431-486.

Byrd, D. (1994) *Articulatory Timing in English Consonant Sequences*. Ph.D. dissertation, University of California at Los Angeles, published as UCLA Working Papers in Phonetics 86.

Cao, J. and I. Maddieson (1992) "An Exploration of Phonation Types in Wu Dialects of Chinese," Journal of Phonetics 20:77-92.

Danstuji, M. (1982) "An Acoustic Study on Glottalized Vowels in the Yi (Lolo) Language," Studia Phonologica XVI:1-11.

Delgutte, B. (1982) "Some Correlates of Phonetic Distinctions at the Level of the Auditory Nerve," in R. Carlson and B. Granström, eds., *The Representation of Speech in the Peripheral Auditory System*. Amsterdam : Elsevier Biomedical, 131-150.

Dhall, G.B. (1966) *Aspiration in Oriya*. Utkal University, Bhubaneswar, Orissa, India.

Diehl, R.L. (1991) "The Role of Phonetics within the Study of Language," Phonetica 48:120-134.

Eglund, S. (1978) *La Intelegibilidad interdialectal en México: Resultados de Algunos Sondeos*. Summer Institute of Linguistics, Mexico.

Fernandez de Miranda, M.T., (1956) *Glotocronologia de la Familia Popoloca*. Seria Cientifica 4. Museo Nacional de Antropologia, Mexico.

Fischer-Jørgensen, E. (1970) "Phonetic Analyses of Breathy (Murmured) Vowels in Gujarati," Indian Linguistics 28:71-140.

Flemming, E. (1995) *Auditory Representations in Phonology*. Ph.D. dissertation, University of California at Los Angeles. Also to appear, *UCLA Occasional Papers in Linguistics, Dissertation Series*.

Foris, D. (1973) "Sochiapan Chinantec Syllable Structure," International Journal of American Linguistics 39-4:232-235.

Fujimura, O. (1979) "Physiological Functions of the Larynx in Phonetic Control," in H. and P. Hollien, eds., *Current Issues in the Phonetic Sciences: Proceedings of the IPS-77 Congress, Miami Beach Florida, 17-19th December 1977, Part I.* Amsterdam : John Benjamins B.V., 129-163.

Fujimura, O. and M. Sawashima (1971) "Consonant Sequences and Laryngeal Control," Annual Bulletin of the Research Institute of Logopedics and Phoniatrics 5:1-7.

Glover, W.W. (1971) "Register in Tibeto-Burman Languages in Nepal: A Comparison with Mon-Khmer," *Papers in South East Asian Linguistics* 2:1-22.

Goldstein, L. (1990) "On Articulatory Binding: Comments on Kingston's Paper," in J. Kingston and M.E. Beckeman, eds., *Between the Grammar and Physics of Speech--Papers in Laboratory Phonology I*. Cambridge University Press, 445-450.

Goldstein, L., and C.P. Browman (1986) "Representation of Voicing Contrasts Using Articulatory Gestures," Journal of Phonetics 14:339-342.

Gregerson, K.J. (1976) "Tongue-Root and Register in Mon-Khmer," in P.N. Jenner, L.C. Thompson, and S. Starosta, eds., *Austroasiatic Studies, Part I*. University of Hawaii Press, 323-369.

Gudschinsky, S.C. (1959) *Proto-Popotecan--A Comparative Study of Popolocan and Mixtecan*. Indiana University Publications in Anthropology and Linguistics. International Journal of American Linguistics Memoir 15. Baltimore : Waverly Press.

Halle, M., and K.N. Stevens (1971) "A Note on Laryngeal Features," Quarterly Progress Report, Research Laboratory of Electronics, Maasachusetts Institute of Technology v.101:198-212.

Haudricourt, A.G. (1954) "De L'Origine des Tons en Vietnamien," Journal Asiatique 242:69-82.

Henderson, E.J.A. (1985) "Feature Shuffling in Southeast Asian Languages," in S. Ratanakul, D. Thomas, and S. Premsrirat, eds., *Southeast Asian Linguistic Studies Presented to Andre-G. Haudricourt*. Bangkok : Mahidol University, 1-22.

Hixon, T.J., J. Mead, and D.H. Klatt (1971) "Influence of Forced Transglottal Pressure Changes on Vocal Fundamental Frequency," Journal of the Acoustical Society of America 49:105.

Hollenbach, B.E. (1977) "Phonetic vs. Phonemic Correspondence in Two Trique Dialects," in W.R. Merrifield, ed., *Studies in Otomanguean Phonology*. Summer Institute of Linguistics/University of Texas at Arlington, 35-68.

Hollenbach, E.E. de (1987) "La Duración Vocalica en el Trique de Copala," Summer Institute of Linguistics Mexico Workpapers 8:15-30.

Hombert, J.-M. (1978) "Consonant Types, Vowel Quality, and Tone," in V. Fromkin, ed., *Tone: A Linguistic Survey*, Academic Press 77-111.

Hombert, J.-M., J.J. Ohala, and W.G. Ewan (1979) "Phonetic Explanations for the Development of Tones," Language 55.1:37-58.

Huffman, M.K. (1987) Measures of Phonation Types in Hmong," Journal of the Acoustical Society of America 81.2:495-504.

Jun, J. (1995) *A Constraint-Based Analysis of Place Assimilation Typology*. Ph.D. dissertation, University of California at Los Angeles. Also to appear, *UCLA Occasional Papers in Linguistics, Dissertation Series*.

Kingston, J. (1985) "The Phonetics and Phonology of the Timing of Oral and Glottal Events," Ph.D. dissertation, University of California at Berkeley.

Kingston, J. (1990) "Articulatory Binding," in J. Kingston and M.E. Beckman, eds., *Between the Grammar and Physics of Speech--Papers in Laboratory Phonology I*. Cambridge University Press, 406-434.

Kingston, J., and A.H. Cohen (1992) "Extending Articulatory Phonology," Phonetica 49:194-204.

Kirk, P.L. (1969) "The Development of Jalapa Mazatec Voiced Aspirates," Linguistic Society of America Annual Meeting, San Francisco.

Kirk P.L. (1966) *Proto-Mazatec Phonology*. Ph.D. dissertation, University of Washington.

Kirk, P.L., J. Ladefoged, and P. Ladefoged (1984) "Phonological Representations of Breathy and Creaky Vowels in Jalapa Mazatec," Paper presented at the 23rd Conference on American Indian Languages, Denver.

Kirk, P.L., J. Ladefoged, and P. Ladefoged (1991) "Acoustic Analysis of Jalapa Mazatec Complex Vowels," Paper Presented to the 47th International Congress of Americanists, New Orleans.

Kirk, P.L., J. Ladefoged, and P. Ladefoged (1993) "Quantifying Acoustic Properties of Modal, Breathy, and Creaky Vowels in Jalapa Mazatec," in A. Mattina and T. Montler, eds., *American Indian Linguistics and Ethnography in Honor of Lawrence C. Thompson*. Occassional Papers in Linguistics 10, University of Michigan, 435-450.

Ladefoged, P. (1958) "Syllables and Stress," Misc. Phonetica 3:1-14.

Ladefoged, P. (1962a) "Sub-Glottal Activity During Speech," in *Proceedings of the Fourth International Congress of Phonetic Sciences*. Mouton and Company, 76-91.

Ladefoged, P. (1963) "Some Physiological Parameters in Speech," Language and Speech 6:109-116.

Ladefoged P. (1968) "Linguistic Aspects of Respiratory Phenomena," Annals of the New York Academy of Sciences 155, Article 1:141-151.

Ladefoged, P., I. Maddieson, and M. Jackson (1988) "Investigating Phonation Types in Different Languages" in O. Fujimora, ed., *Voice Production, Mechanisms, and Functions*. New York : Raven Press, Ltd., 297-317.

Laver, J. (1980) *The Phonetic Description of Voice Quality*. Cambridge University Press.

Lee, C.Y. and T.S. Smith (1971) "A Study of Subglottal Air Pressure in Korean Stop Consonants," Preliminary version, presented at the 82nd meeting of the Acoustical Society of America, Denver.

Lieberman, P., R. Knudson, and J. Mead (1969) "Determination of the Rate of Change of Fundamental Frequency with Respect to Subglottal Air Pressure During Sustained Phonation," Journal of the Acoustical Society of America 45.6:1537-1543.

Lisker, L., A.S. Abramson, F.S. Cooper, and M.H. Schvey (1969) "Transillumination of the Glottis in Running Speech," Journal of the Acoustical Society of America 45.6:1544-1546.

Löfqvist, A. (1980) "Interarticulator Programming in Stop Production" Journal of Phonetics 8:475-490.

Lombardi, L. (1991) "Laryngeal Features and Laryngeal Neutralization," Ph.D. dissertation, University of Massachusetts at Amherst.

Longacre, R. (1952) "Five Phonemic Pitch Levels in Trique," Acta Linguistica VII,1-2:62-82.

Longacre, R. (1957) *Proto Mixtecan*. Indiana University Research Center in Anthroplogy, Folklore, and Linguistics 5.

Longacre, R.E. (1959) "Trique Tone Morphemics," Anthropological Linguistics 1.4:5-42.

Longacre, R.E. (1966) "On the Linguistic Affinities of Amuzgo," International Journal of American Linguistics 32:46-49.

Longacre, R.E., and R. Millon (1961) "Proto-Mixtecan and Proto-Amuzgo-Mixtecan Vocabularies," Anthropological Linguistics 3.4:1-44.

Lyman, T. (1974) *Dictionary of Hmong Njua*. The Hague : Mouton.

Maddieson, I. (1984) *Patterns of Sounds*. Cambridge University Press.

Maddieson, I. (1986) "The Size and Structure of Phonological Inventories: Analysis of UPSID," in J.J. Ohala and J.J. Jaeger, eds., *Experimental Phonology*. Academic Press, 105-124.

Maddieson, I. (1993a) "Sequence in Simultaneity: Phonetic 'Enhancements" in Ewe Doubly-Articulated Stops," Paper presented at Linguistic Society of America Annual Meeting.

Maddieson, I. (1993b) "Investigating Ewe Articulations with Electromagnetic Articulography," Forschungsberichte des Instituts für Phonetik und Sprachliche Kommunication der Universität München 31:181-214.

Maddieson, I., and P. Ladefoged (1985) "'Tense' and 'Lax' in Four Minority Languages of China," Journal of Phonetics 13:433-454.

Mak, C., and R. Longacre (1960) "Proto-Mixtec Phonology," International Journal of American Linguistics 26.1:23-40.

Martinet, A. (1952) "Function, Structure, and Sound Change," Word 8.1:1-32.

Mattingly, I.G. (1981) "Phonetic Representations and Speech Synthesis by Rule," in T. Myers, J, Laver, and J. Anderson, eds., *The Cognitive Representation of Speech*. Amsterdam : North Holland Publishing Company, 415-419.

McCarthy, J.J., and A.S. Prince (1993) "Prosodic Morphology I," Manuscript, University of Massachusetts at Amherst, and Rutgers University.

Mugele, R.L. (1982) "Tone and Ballistic Syllable in Lalana Chinantec," Ph.D. dissertation, University of Texas at Austin.

Ohala, J. (1975) "Phonetic Explanations of Nasal Sound Patterns," in C.A. Ferguson, L.M. Hyman, and J.J. Ohala, eds., *Nasálfest: Papers from a Symposium on Nasals and Nasalization*. Language Universals Project, Stanford University, 289-316.

Ohala, J.J. (1978) "Production of Tone, " in V. Fromkin, ed., *Tone: A Linguistic Survey*, Academic Press.

Ohala, J. (1983) "The Origins of Sound Patterns in Vocal Tract Constraints," in P.F. MacNeilage, ed., *The Production of Speech*. Springer-Verlag.

Ohala, J.J. (1990) "Respiratory Activity in Speech," in W.J. Hardcastle and A. Marchal, eds., *Speech Production and Speech Modeling*. Amsterdam : Kluwer Academic Publishers, 23-53.

Ohala, J.J. (1992) What's Cognitive, What's Not, in Sound Change," in G. Kellerman and D. Morrissey, eds., *Diachrony Within Synchrony: Language and Cognition*. Frankfurt/M : Peter Lang Verlag, 309-355.

Ohala, J.J. and W.G. Ewan (1973) "Speed of Pitch Change," Abstract, Journal of the Acoustical Society of America 53:345.

Patel, M.S. and J.J. Mody (1961) *The Vowel System of Gujarati*. Faculty of Education and Psychology, Maharaja Sayajirao University of Baroda, Baroda.

Pace, W.J. (1990) "Comaltepec Chinantec Verb Inflection," in W.R. Merrifield and C.R. Rensch, eds., *Syllables, Tone, and Verb Paradigms.* Studies in Chinantec Languages v.4. Summer Institute of Linguistics, 21-62.

Parker, S. (1994) "Laryngeal Codas in Chamicuro," International Journal of American Linguistics 60.3:261-271.

Pike, K.L. and E.V. Pike (1947) "Immediate Constituents of Mazateco Syllables," International Journal of American Linguistics 13.2:78-91.

Plomp, R. (1967) "Pitch of Complex Tones," Journal of the Acoustical Society of America 41.6:1526-1533.

Prince, A., and P. Smolensky (1993) "Optimality Theory--Constraint Interaction in Generative Grammar," Manuscript, Rutgers University, and University of Colorado at Boulder.

Ratliff, M. (1992) *Meaningful Tone: A Study of Tonal Morphology in Compounds, Form Classes, and Expressive Phrases in White Hmong*. Center for Southeast Asian Studies, Monograph Series on Southeast Asia, Special Report 27, Northern Illinois University.

Remez, R.E. and P.E. Rubin (1993) "On the Intonation of Sinusoidal Sentences," Journal of the Acoustical Society of America 94.4:1983-1988.

Rensch, C.R. (1968) *Proto Chinantec Phonology*. Papeles de la Chinantla VI. Seria Cientifica 10. Museo Nacional de Antropologia, Mexico.

Rensch, C.R. (1976) *Comparative Otomanguean Phonology*. Indiana University, Bloomington.

Rensch, C.R. (1977) "Classification of the Otomanguean Languages and the Position of Tlapanec," in *Two Studies in Middle American Comparative Linguistics,* Summer Institute of Linguistics/University of Texas at Arlington, 53-108.

Rensch, C.R. (1978) "Ballistic and Controlled Syllables in Otomanguean Languages," in A. Bell and J.B. Hooper, eds., *Syllables and Segments*. Amsterdam : North Holland Publishing Company, 85-92.

Rensch, C.R. (1989) *An Etymological Dictionary of the Chinantec Languages*. Studies in Chinantec Languages v.1. Summer Institute of Linguistics.

Rensch, C.R., and C.M. Rensch (1966) "The Lalana Chinantec Syllable," in *Summa Anthropologica en homenaje a Roberto J. Weitlaner*. Instituto Nacional de Antropologia E Historia, Mexico, 455-463.

Ritsma, R.J. (1967) "Frequencies Dominant in the Perception of the Pitch of Complex Sounds," Journal of the Acoustical Society of America 42.1191-198.

Rosenberg, A.E. (1965) "Pitch Discrimination of Jittered Pulse Trains," Journal of the Acoustical Society of America 39.5:920-928.

Rothenberg, M. (1968) *The Breath-Stream Dynamics of Simple Released-Plosive Production*. Basel : S. Karger.

Ruiz de Bravo Ahuja, G. (1975) *Trique--San Juan Copala, Oaxaca*. Instituto de Investigacion e Integracion Social del Estado de Oaxaca, Mexico.

Sawashima, M. and H. Hirose (1983) "Laryngeal Gestures in Speech Production," Annual Bulletin of the Research Institute of Logopedics and Phoniatrics 14:29-51.

Sawashima, M. and H. Hirose (1983) "Laryngeal Gestures in Speech Production," in P.F. MacNeilage, ed., *The Production of Speech*. Springer-Verlag, 11-38.

Sawashima, M. and S. Miyazaki (1973) "Glottal Opening for Japanese Voiceless Consonants," Annual Bulletin of the Research Institue of Logopedics and Phoniatrics 7:1-9.

Shipp, T., and R.E. McGlone (1971) "Laryngeal Dynamics Associated with Voice Frequency Change," Journal of Speech and Hearing Research 14:761-768.

Silverman, D. (1994a) "A Case Study in Acoustic Transparency: [spread glottis] and Tone in Otomanguean Languages," presentation at North Eastern Linguistics Society 24.

Silverman, D. (1994b) "A Case Study in Acoustic Transparency: [spread glottis] and Tone in Chinantec," in M. Gonzalez, ed., *Proceedings of North Eastern Linguistics Society 24*, 559-572.

Silverman, D. (1995a) "Optimal and Sub-Optimal Timing Relations Between Stops, Vowels, and Vocal Fold Spreading," NELS 26, Harvard University, and Massachusetts Institute of Technonology.

Silverman, D, (1995b) Phasing and Recoverability. UCLA Occassional Papers in Lingusitcs #15, Dissertation Series #1.

Silverman, D. (1995c) "Comaltepec Chinantec Tonology," Manuscript, University of California at Los Angeles.

Silverman, D., B. Blankenship, P. Kirk, and P. Ladefoged (1995) "Phonetic Structures in Jalapa Mazatec," Anthropological Linguistics 37.1:70-88.

Smith, K.D. (1968) "Laryngealization and De-Laryngealization in Sedang Phonemics," Linguistics 38:52-69.

Steriade, D. (1990) "Gestures and Autosegments: Comments on Browman and Goldstein's Paper," in J. Kingston and M.E. Beckman, eds., *Papers in Laboratory Phonology I: Between the Grammar and the Physics of Speech*. Cambridge University Press, 382-397.

Steriade, D. (1992) "Segments, Contours and Clusters," Manuscript, University of California at Los Angeles.

Steriade, D. (1994c) "Complex Onsets as Single Segments: The Mazateco Pattern" in J. Cole and C. Kisseberth, eds., *Perspectives in Phonology*. CSLI Publications, Stanford University, 203-292.

Sundberg, J. (1973) "Data on Maximum Speed of Pitch Changes," Quarterly Progress and Status Reports, Speech Transmission Laboratory, Stockholm, Sweden 4:39-47.

Swadesh, M. (1960) "The Oto-Manguean Hypothesis and Macro-Mixtecan," International Journal of American Linguistics 26:79-111.

Taylor, G.P. (1985) *The Student's Grammar of Gujarati*. Asian Educational Services, New Delhi.

Thelin, A. (1980) "Tlacoatzintepec Chinantec Syllable Structure," Summer Institute of Linguistics Mexico Workpapers 4:1-8.

Titze, I.R. (1989) "On the Relation Between Subglottal Pressure and Fundamental Frequency in Phonation," Journal of the Acoustical Society of America 85.2:901-906.

Tyler, R.S., Q. Summerfield, E.J. Wood, and M.A. Fernandez (1982) "Psychoacoustic and Phonetic Temporal Processing in Normal and Hearing-Impaired Listeners," Journal of the Acoustical Society of America 72:740-752.

Zsiga, E.C. (1993) Features, Gestures, and the Temporal Aspects of Phonological Organization," Ph.D. dissertation, Yale University.

Zsiga, E.C., and D. Byrd (1990) "Acoustic Evidence for gestural Overlap in Consonant Sequences," Journal of the Acoustical Society of America 88.10.