Acoustic dispersion,
and the functional relevance of speech variation

Daniel Silverman
dan.silverman@mcgill.ca
McGill, March 16, 2007

"The history of life is not necessarily progressive; it certainly is not predictable. The earth's creatures have evolved through a series of contingent and fortuitous events."

-Stephen Jay Gould

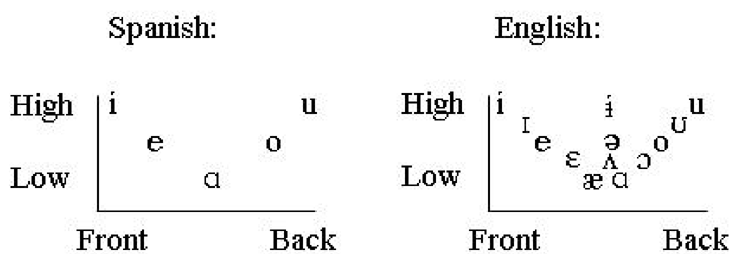
"The history of phonological systems is not necessarily progressive; it certainly is not predictable. The sounds of languages have evolved through a series of contingent and fortuitous events."

- Joe Schmoe

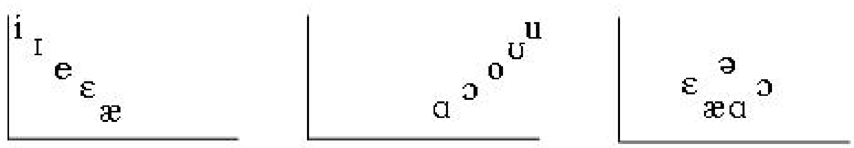
1. SETTING THE THEORETICAL AND METHODOLOGICAL SCENE

- The dispersion of contrastive elements has long been noted by phonologists and phoneticians.

1. This looks familiar:



2. But this is never seen:



- Sapir (1925): asymmetrically distributed elements possess a "psychological aloofness from all other members of the system." We can "feel in [our] bones" a misplaced element.
- Martinet (1952), Hayes (1996): cognitive pressure towards systemic symmetry.
- Kingston and Diehl (1994): Speakers choose different pronunciations of a phoneme in order to optimize conveying the contrast in each context that it occurs.
- Flemming (1995, 2001): Grammatically active constraints to maximize contrastiveness with minimal articulatory effort
- Steriade (2001): "The proposal is to let a distinct grammatical component, which I call the P-map, project correspondence constraints and determine their ranking. The P-map is a set of statements about absolute and relative perceptibility of different contrasts, across the different contexts where they might occur. For instance, the P-map will be the repository of the speaker's knowledge that the

[p]-[b] contrast is better perceived before V's (e.g. in [apa] vs. [aba]) than before C's (e.g. in [apta] vs. [abta])."

- Kingston (2002): "Speakers must be altruists."

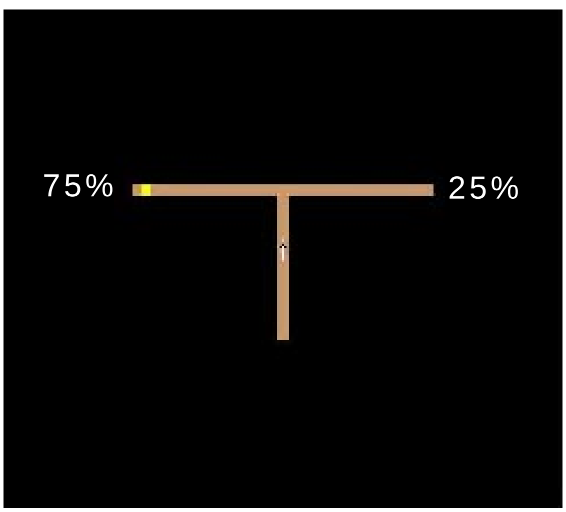
- I propose a shifting the locus of the mechanism
  -from speaker to listener
  -from the synchronic to the diachronic
  -from the teleological to the evolutionary.

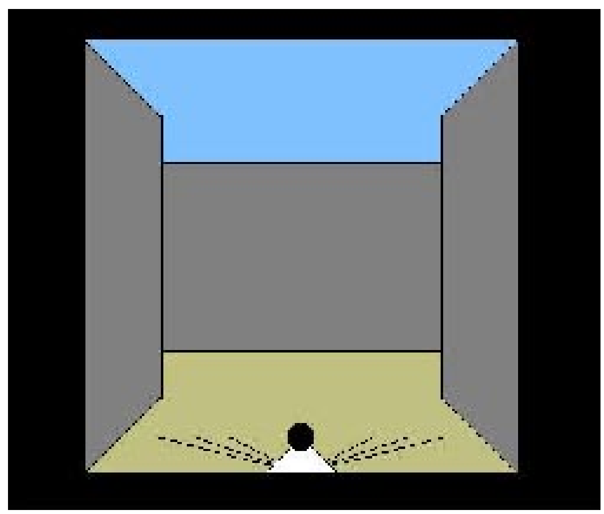
  →Phonetic Pressures
  →Functional Pressures
  →Diachronic Pressures

- Acoustic dispersion is a consequence of the communicative success or failure of the word variants that we use. Successful speech propagates; today's spontaneous, unplanned innovation may become tomorrow's new norm.

PROBABILITY MATCHING

- Probability matching in lower animals (Gallistel 1990, Labov 1994)





- Gallistel (1990:352ff.): Rats in a T-Maze were rewarded with food 75% of the time at one end, 25% of the time at the other. When provided with feedback, rats matched the probability of reward—running to the one end 75% of the time, the other end 25% of the time—despite the fact that they would receive more rewards if they ran to the one end 100% of the time.
- Humans engage in similar behavior in terms of speech production: learners come to largely reproduce the nuances of variation they perceive their elders engaging in, despite the fact that certain of these variants are more successful at keeping contrastive elements distinct.
- Probability matching in language has been observed in natural language settings (Poplack 1980a,b), and in laboratory settings (Hudson and Newport 1999).
- *Speech variation is conventionalized on a language-specific basis.*

- Nonetheless, sound changes may slowly progress due to phonetic and/or functional factors, which influence the perception of the speech signal, consequently affecting the variability over which probabilities are matched.
- Most important in these sorts of changes: the consequences of misperception (Labov 1994)

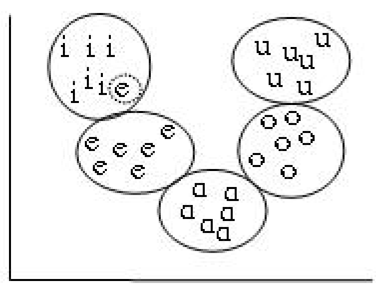
EXEMPLAR THEORY
- Perceptual categories are defined as the set of all experienced instances of the category, such that variation among tokens actually contributes to the categorical properties themselves (e.g. Nosofsky, 1986,8).
- One generation's variation serves as the next generation's template for copy.

PROBABILITY MATCHING PROMOTES CATEGORY SEPARATION AND PHONETIC STABILITY

- Reproduction is never perfect: note the stray token of an "e" word that sounds like [i]

(3)

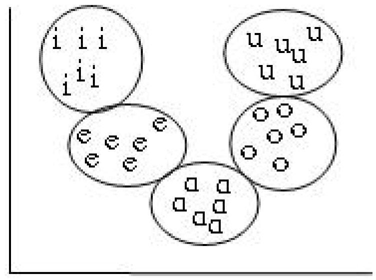
Vowel production:



- Perception is never perfect: this token could be misperceived by listeners, or perhaps ignored.
- Ambiguous tokens are poor exemplars, and so are poorly communicated; they may be passively filtered out of the pool over of tokens over which probabilities are matched.
- Since listeners can only match probabilities to their *perceptions* of speakers' productions, and not to speakers' productions directly, they might conclude that the variation in the speech signal is *not as extensive* as it actually is, and match this in their own productions, accordingly.
- Categories naturally maintain phonetic buffer regions among themselves:

(4)

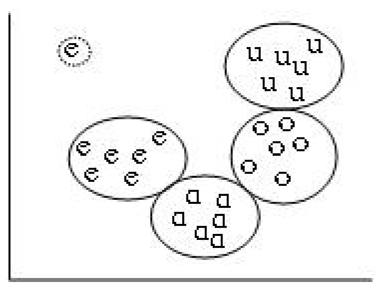
Vowel perception:



PROBABILITY MATCHING PROMOTES CATEGORY SEPARATION AND PHONETIC *CHANGE*

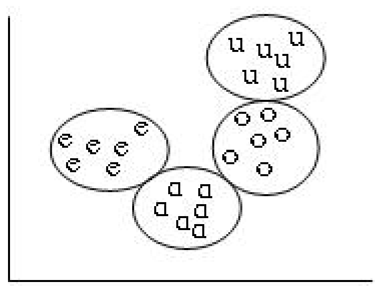
- A wild stray in a(n admittedly strange though nicely illustrative) four-vowel system…
  (5)

Vowel production:



- …will be thrown out, perhaps to be laughed at.
  (6)

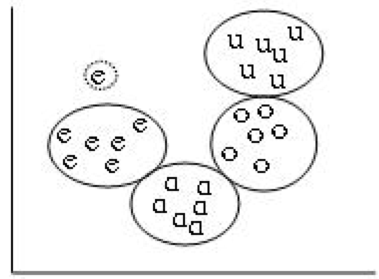
Vowel perception:



- But a mild stray…

(7)

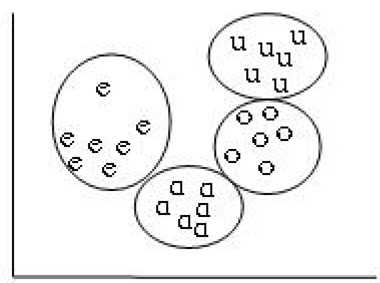
Vowel production:



- …is better separated from other categories, and may be communicated successfully.

(8)

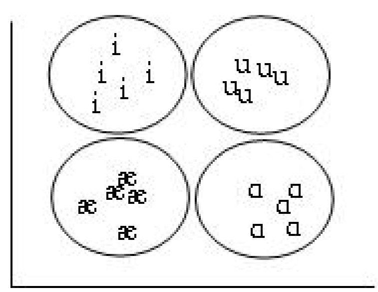
Vowel perception:



- The elements come to disperse themselves, availing themselves of the entirety of the acoustic space.

(9)

Newly evolved system:



2. EXEMPLIFICATION: COMALTEPEC CHINANTEC TONE SANDHI

- Comaltepec Chinantec is a Chinantecan language of the Otomanguean group, spoken by about 90,000 people in the state of Oaxaca, Mexico (Grimes 2003).
- High tones spread rightward from Low-High syllables (Pace 1990, Silverman 1995,7, 2006)

(10)

non-sandhi context:		sandhi context:	gloss:
kwa˩˥	toː˩	kwa˩˥ toː˥˩	give a banana
kwa˩˥	ŋɨh˩	kwa˩˥ ŋɨh˥˩	give a chayote
kwa˩˥	kuː˧	kwa˩˥ kuː˥˧	give money
kwa˩˥	^{n}dʒuː˧	kwa˩˥ ^{n}dʒuː˥˧	give a jug

This alternation never neutralizes contrasts; all outputs are allophonic

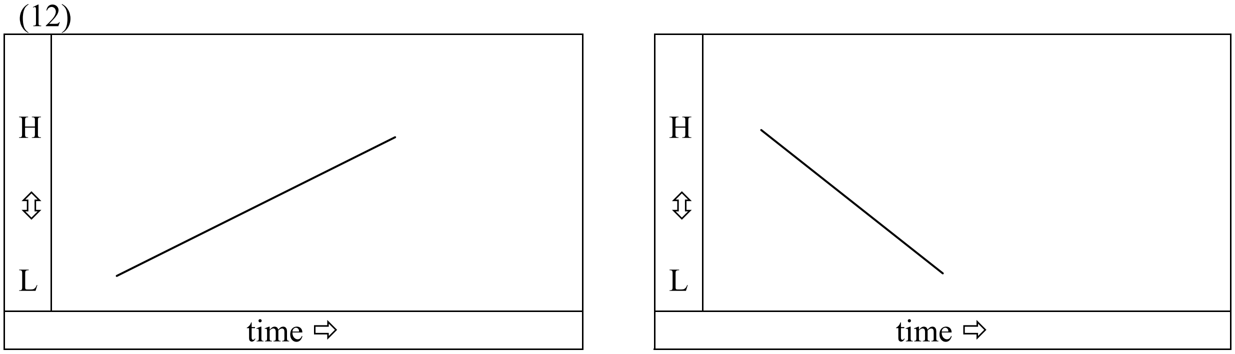
(11)

L	M	H	LM	LH	HL	HM	MH	gloss:
[toː˩]					[toː˥˩]			banana
	[kuː˧]					[kuː˥˧]		money
		[li˥]						flower
			[ki˩˧]					garbage
				[bʌʔ˩˥]			[bʌʔ˧˥]	ball

→Phonetic Pressures:

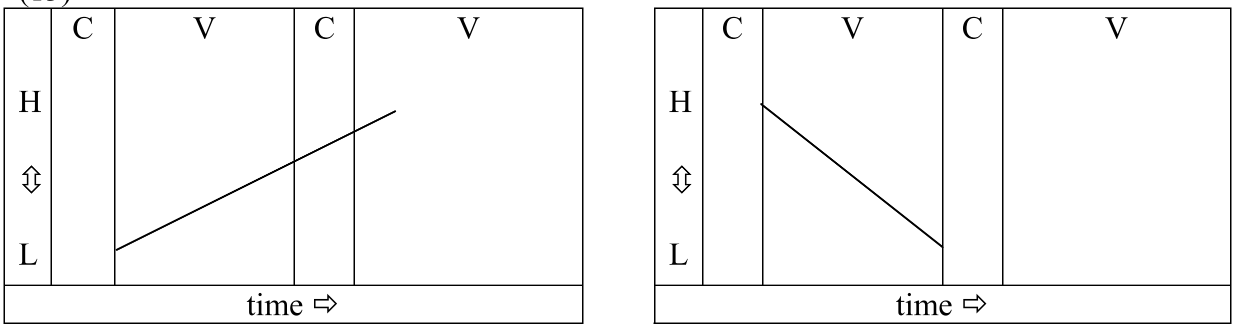
- Pitch rises take longer to implement than do pitch falls (Ohala 1979, Sundberg 1979)

(12)



- "...[S]ince falling tones can be produced faster than rising tones...they might be less likely to 'spill over' onto the next syllable." (Ohala 1978:31)

(13)

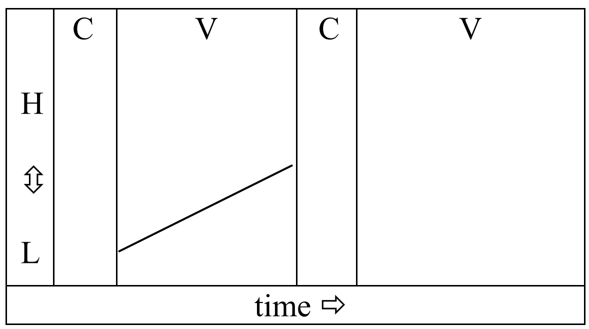


- Phonetic explanations alone cannot fully account for language-specific production conventions, but nonetheless might serve to constrain the general direction of sound change—this is where functional pressures on the system become relevant.

→Functional Pressures:

- non-spread might neutralize contrasts (the tone may sound like LM)

(14)



- Remember: the outputs of tone sandhi are never neutralizing.
- Spreading the tone increases the likelihood that all contrastive values are effectively transmitted.

→Diachronic pressures:

(15)

[[V˩˥CV˧]]………	[V˩˥CV˥˩]]	[[V˧˥CV˧]]………	[V˧˥CV˥˩]]
less distinct from [V˧˥CV˧]	more distinct from [V˧˥CV˧]	more distinct from [V˩˥CV˥˩]	less distinct from [V˩˥CV˥˩]
less likely perceived unambiguously	more likely perceived unambiguously	more likely perceived unambiguously	less likely perceived unambiguously
less likely produced	more likely produced	more likely produced	less likely produced

∴ gradual move towards [[V˩˥CV˥˩]]

∴ stability of [V˧˥CV˧]]

- Physical properties of the speech mechanism—phonetic factors—may induce a delay in achieving higher pitch in the context of preceding lower pitch.
- But independent functional factors may induce the conventionalization of high tone spread. As LH tones are less likely to neutralize upon spreading, displaced tokens are less often ambiguously perceived, hence more likely to be reproduced.
- The variability inherent in speech production may be the fodder for these sorts of sounds changes: the more distinct the variant from an acoustically similar contrastive value, the more likely the system will wend towards this variant.
- This scenario demonstrates how very minor phonetic tendencies, coupled with the sporadic lexical semantic ambiguities they might induce or eschew, may eventually have far-reaching consequences for the phonological system.

Dissimilar languages possess similar patterns

- <u>Mbui Bamileke</u> (Cameroon): high tones often shift from a leftward syllable to a rightward syllable (Hyman and Schuh 1974)

(16)

non-sandhi context:	sandhi context:	gloss:
lɔ̀ɔ́ , bə̀sə́ŋ	lɔ̀ɔ̀ bə́sə́ŋ	look for the birds
lɔ̀ɔ́ , tìè	lɔ̀ɔ̀ tíè	look for the pot
lɔ̀ɔ́ , sə́ŋ	lɔ̀ɔ̀ sə́ŋ	look for the bird

- <u>Quiotepec Chinantec</u> (Mexico): an arbitrary set of open, “ballistic” ([´]) syllables possessing M or LM tones is raised to H in the context of a preceding LH or MH contour (Gardner and Merrifield 1990)

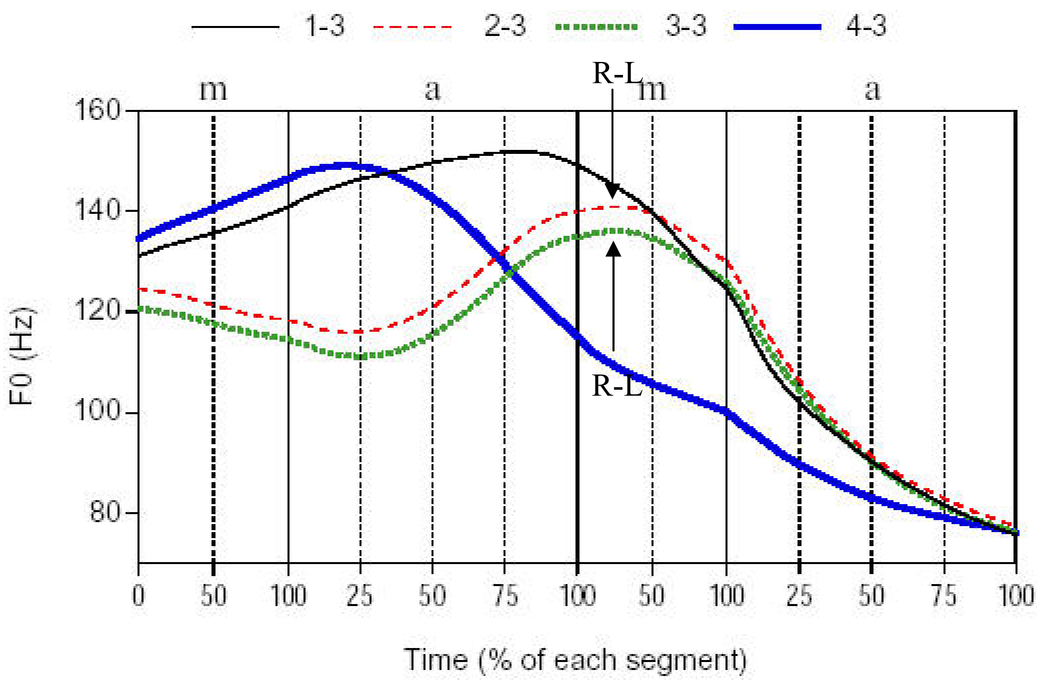
(17)

non-sandhi context:		sandhi context:	gloss:
kʷó˦˥	tű̃˧	kʷó˦˥ tű̃˥	give (me) two
cý:˦˥	tʲý˨˩	cý:˦˥ tʲý˥	good earthen jar
sí:˩˥	dʲá˧	sí:˩˥ dʲá˥	shave down ten
ʃýʔ˩˥	tʲúj˧	ʃýʔ˩˥ tʲúj˥	good armadillo
ʃýʔ˩˥	bő̃˧	ʃýʔ˩˥ bő̃˥	stupid armadillo

- Beijing Mandarin (China): tones with high offsets typically peak only after the following consonant has been implemented; tones with low offsets show a significantly lesser spill-over effect in these same contexts (Xu 1997, Xu and Wang 2001; pitch track kindly provided by Yi Xu).

(18)

[mama] 1-3 = H-L 2-3 = R-L 3-3 = R-L 4-3 = F-L



- When the tonal system is uncrowded, the spill-over effect may be greater

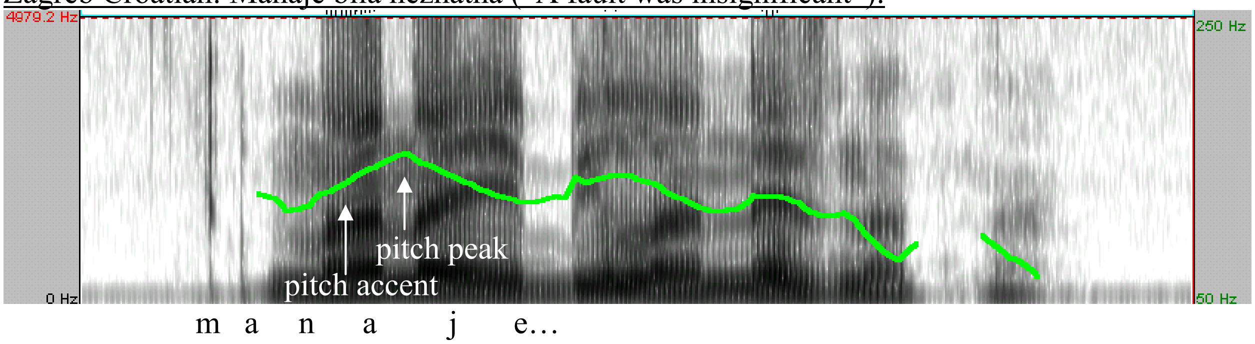
- Digo (Kenya): high tone verbs spill their high component into the suffix domain, except when a voiced obstruent blocks its propagation. (Actually, *any* preceding high tone migrates to the penult-final border region.) (Kisseberth 1984, Yip 2002)

(19)

"toneless" verbs:	gloss:	high-toned verbs:	gloss:
ku˨ri˧ma˨	to cultivate	ku˨a˧ru˧˥ka˥˨	to begin
ku˨am˨bi˨ra˨	to tell	ku˨fu˨ru˨ku˧˥ta˥˨	to move restlessly
ku˨gan˧da˨mi˨za˨	to press	ku˨fu˨ki˦za˨	to apply heat

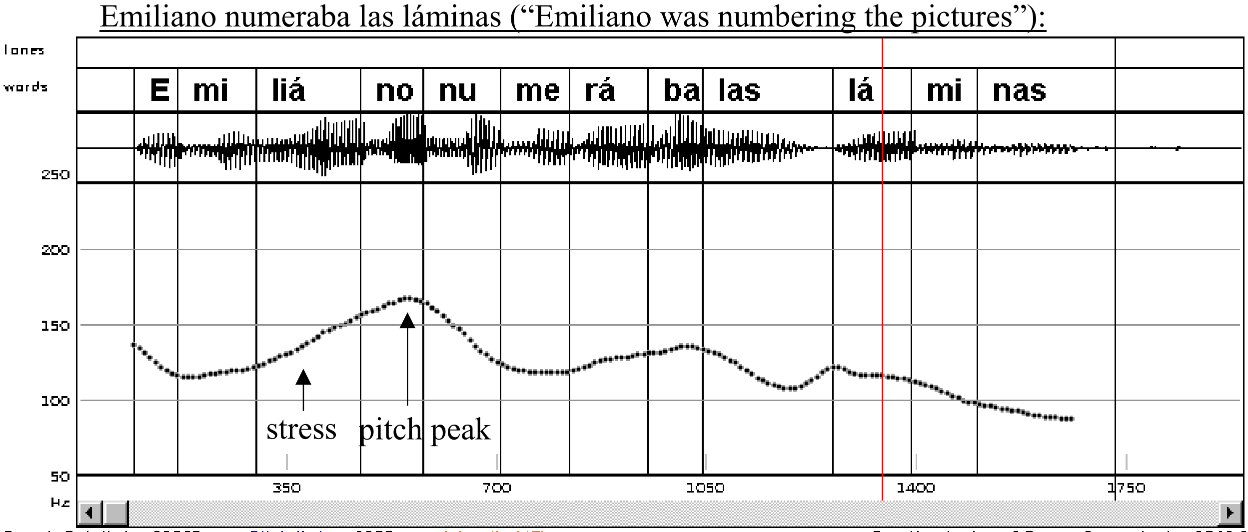
- Zagreb Croatian (Croatia): high pitch-accented syllables possess a rising pitch contour, pitch peaks being realized on the post-tonic syllable, rather than on the accented syllable itself (Lehiste and Ivic 1986; spectrogram kindly provided by Rajka Smilanic).

(20)
Zagreb Croatian: Manaje bila neznatna ("A fault was insignificant"):



- Peninsular Spanish (Spain): stressed syllables typically possess a pitch rise, with the pitch peak being realized on the post-stressed syllable (Navarro-Tomás 1944, Fant 1984, Prieto, van Santen, and Hirschberg 1995; pitch track kindly provided by Jose Ignacio Hualde).

(21)
Emiliano numeraba las láminas ("Emiliano was numbering the pictures"):



- When the tone system is more crowded, subphonemic vowel lengthening is often found.
- Cantonese (China): Checked syllables with (derived) rising tones are significantly longer than checked syllables with level tones (Yu, in prep)

(22)

“morphologically-derived” rising tones on checked syllables:	gloss:	“sandhi-derived” rising tones on checked syllables:	gloss:
saː˥ kɔˑk̚˧˥	(a type of food)	tsʰaˑt̚˧˥ tsʰat̚˧	to brush a little
tsʊk̚˥ tsʰaˑt̚˧˥	a bamboo brush	pʰaˑk̚˧˥ pʰak̚˧	to hit a little
pɔ˥ pʰaˑk̚˧˥	a ball racket	kɛˑp̚˧˥ kɛp̚˧	to clip a little
puj˥ tɔˑk̚˧˥	a cup stand	tʰɔˑk̚˧˥ tʰɔk̚˧	to support a little
fɔŋ˥ kaˑk̚˧˥	a square	kaˑk̚˧˥ kak̚˧	to separate a little
kʌːm˥ tʃʰaˑp̚˧˥	a golden insert	tʃʰaˑp̚˧˥ tʃʰap̚˧	to insert a little
kʌːm˥ tsɔˑk̚˧˥	a golden chisel	tsɔˑk̚˧˥ tsɔk̚˨	to chisel a little
kɛj˥ jiˑp̚˧˥	propeller	tiˑp̚˧˥ tip̚˨	to pile up a little

- Mitla Zapotec (Mexico): four tones, high, low, rising, falling: “The vowel of a stem-final syllable having a low-high glide is somewhat lengthened.” (Briggs 1961:2)
- Thai (Thailand): vowels with rising tones in Thai are longer than other vowels (Gandour 1977)

Zhang’s report (2001):

- Ga (Ghana): rising tones on final vowels trigger lengthening (Paster 1999)
- Konni (Ghana): rising tones can only occur on final CVN or CVVN syllables, whereas falling tones may be found on final CV syllables (Cahill 1999)
- Tiv (Nigeria): contour tones are restricted to word-final position. Especially relevant is the fact that HL may occur on CV, but LH may occur only on CVR (R=resonant). (Pulleyblank 1986)

- The upshot: In these rising contexts, particular tokens that had a little more vowel length were better at conveying the contrastive cues to listeners. In turn, these listeners recovered the semantic content intended by speakers, and the lengthening took hold in the system.

3. EXEMPLIFICATION: TRIQUE LABIAL HARMONY

- Trique is a Mixtecan language of the Otomanguean group, spoken by about 23,000 people in the states of Oaxaca, Guerrero, and Puebla, Mexico (Grimes 2003).
- Round vowels spread rightward across velars, but not across alveolars (there are no labial consonants in this context)

(23) Trique segment inventory:

p	t			k	iː			uː
b	d			g		e(ː)	o(ː)	
ts	tʃ	ʈʂ				a(ː)		
		s	ʃ	ʂ				
		z	ʒ	ʐ				
m	n							

l

w j

ʔ,h

(24)

Trique trans-velar spreading:

nuk^{w}ah	strong	duk^{w}a	possessed house
dug^{w}ah	to twist	zug^{w}i	(name)
ʒug^{w}a	to be twisted	dug^{w}e	to weep
dug^{w}ane	to bathe (someone)	rug^{w}i	peach
rug^{w}ah	hearth stones	dug^{w}i	together with, companion

(25)

Trique round vowel - alveolar sequences:

rune	large black beans	utah	to anoint
utʃe	to get wet	utʃi	to nurse
uta	to gather	duna	to leave something
gunah	to run	rudaʔa	stone rolling pin
ʒutʃe	hens, domestic fowl	gunɨ	to hear

→Phonetic Pressures

- Historically, Trique had *uk and *ut, but not *uk^w (nor *ut^w) (Longacre 1957, 62)
- Why should a labial glide have evolved in the *uk context, and not in the *ut context?
- There's no *intrinsic* phonetic motivation for this sound change. We have to look elsewhere…

→Functional Pressures

- The spreading asymmetry may serve to enhance the acoustic distinction between the velar and alveolar places of articulation.
- Accompanying trans-alveolar spreading, by contrast, would serve to *diminish* the velar-alveolar acoustic distinction.

(26)

F2 onset values:

		New York:		Ohio:
[uda]:	a.	**1700 Hz**	b.	**1700 Hz**
[ud^{w}a]:		1200 Hz		1000 Hz
[uga]:		1500 Hz		1300 Hz
[ug^{w}a]:		**1000 Hz**		**900 Hz**

(27)
F2 onset values of New York English, and the proposed Trique diachrony:

proto-form: ↓							*uga		*uda ↓	
current form:		[ug^{w}a] ←		([ud^{w}a])					[uda]	
F2 (Hz):	900	1000	1100	1200	1300	1400	1500	1600	1700	1800

- By considering the acoustic and consequent functional benefit of spreading labiality across velars—a pattern which might be present due to the variation inherent in speech production—and the counter-functionality of spreading labiality across alveolars, we might motivate the Trique sound change.

(28)
→Diachronic pressures:

[uga......ug̹a......ug^{w}a]

[uga]	[ug^{w}a]
less distinct from [uda]	more distinct from [uda]
less likely perceived unambiguously	more likely perceived unambiguously
less likely produced	more likely produced

∴ gradual move towards [ug^{w}a]

[uda......ud̹a......ud^{w}a]

[uda]	[ud^{w}a]
more distinct from [ug$^{(w)}$a]	less distinct from [ug$^{(w)}$a]
more likely perceived unambiguously	less likely perceived unambiguously
more likely produced	less likely produced

∴ stability of [uda]

Experiment

- Noise introduced into the speech signal might induce a "sped-up" rate of misperception in certain contexts, and thus reflect one origin of real-world sound change (Silverman 2006).
- Subjects listen to [udɑ], [ud^{w}ɑ], [ugɑ], [ug^{w}ɑ] in various levels of "white noise"
- Listeners were far more likely to hear [udɑ] as [ugɑ] than they were [udɑ] as [ug^{w}ɑ].
- [udɑ] and [ug^{w}ɑ] were the least often confused with each other.

(29) F2-based confusion matrix

perceived↘ presented↓	Level 1	Level 2 (Nearest F2)	Level 3 (Mid F2)	Level 4 (Furthest F2)
uda	uda 1208	uga (200 Hz) 145	ud^{w}a (500 Hz) 40	ug^{w}a (700 Hz) 17
ud^{w}a	ud^{w}a 812	ug^{w}a (200 Hz) 291	uga (300Hz) 71	uda (500 Hz) 223
uga	uga 964	uda (200 Hz) 355	ud^{w}a (300 Hz) 43	ug^{w}a (500 Hz) 47
ug^{w}a	ug^{w}a 879	ud^{w}a (200 Hz) 501	uga (500 Hz) 14	uda (700 Hz) 15

- A repeated measures ANOVA confirmed a main effect for F2 similarity, $F(3, 27)=158.6$, $p<.001$. Pairwise comparisons with Bonferroni adjustment revealed a significant difference between Levels 1 and 2, and between Levels 2 and 3 ($p<.001$). The difference between Levels 3 and 4 was not significant ($p>.05$), even when including the idiosyncratic responses of the two aforementioned subjects, suggesting that when F2 differences surpassed a certain value, the rate of misperception leveled off. Mean responses for each level are graphically displayed in (11).

4. EXEMPLIFICATION: INTERVOCALIC OBSTRUENTS IN CORSICAN

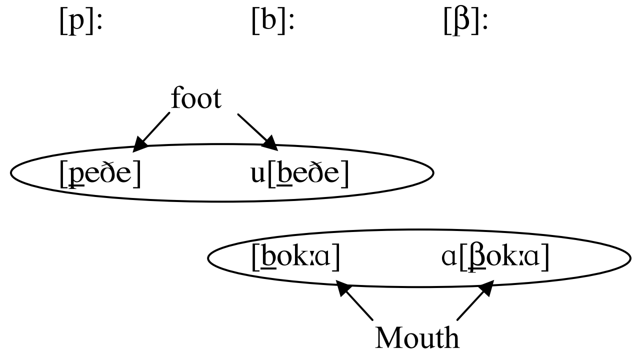
- Phonetically conditioned sound changes can trigger phonological responses

(30) Corsican (France) (Dinnsen and Eckman 1977);

# ___:			V ___V:	
Voiceless stops:		⇔	Voiced stops:	
peðe	'foot'		u beðe	'the foot'
tengu	'I have'		u dengu	'I have it'
sɑkːu	'bag'		u zɑkːu	'the bag'
⇕			⇕	
Voiced stops:		⇔	Voiced fricatives:	
bokːɑ	'mouth'		ɑ βokːɑ	'the mouth'
dente	'tooth'		u ðente	'the tooth'
ɡolɑ	'throat'		diɣolɑ	'of throat'

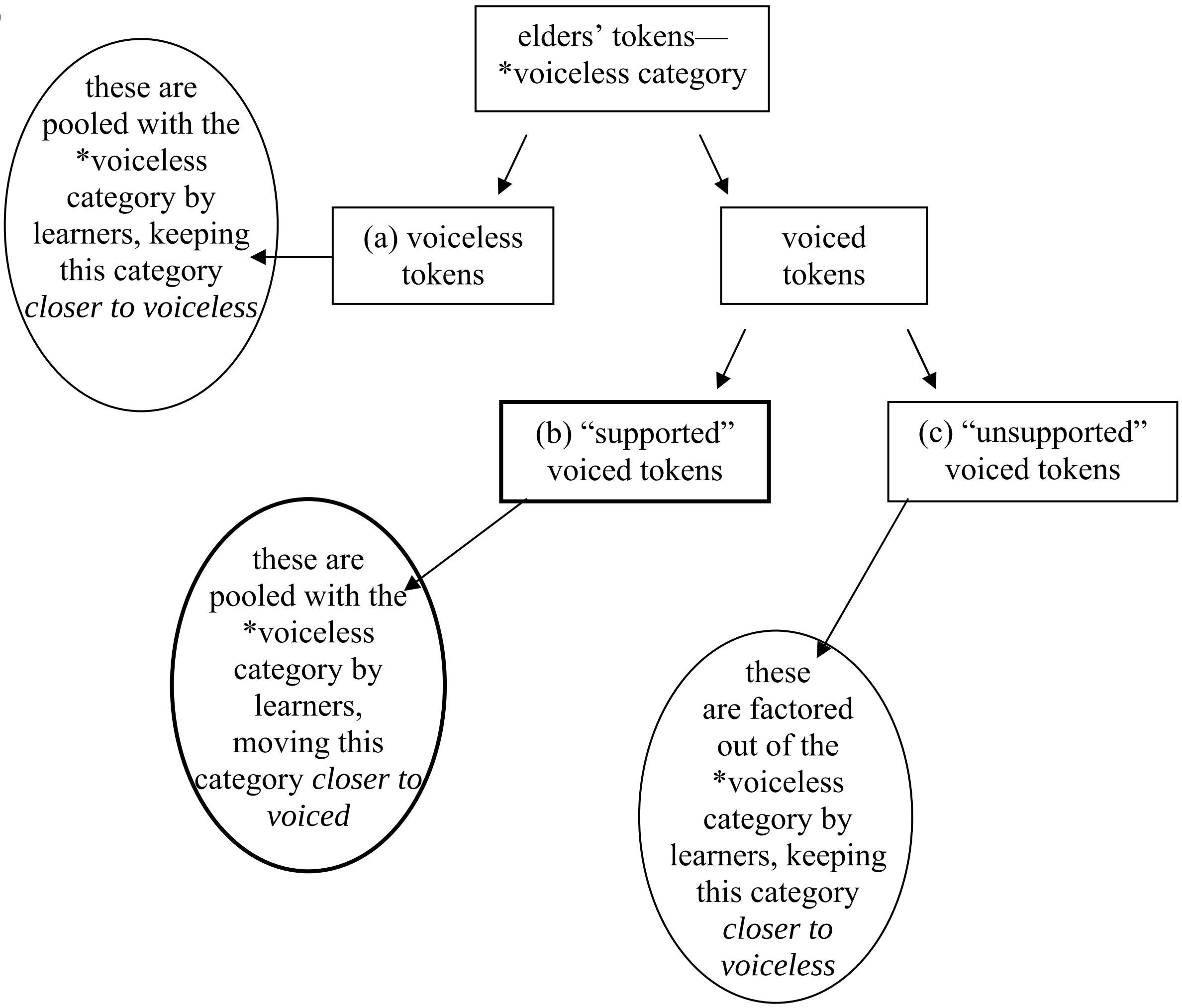
- Intervocalic voicing is phonetically natural
- Intervocalic spirantization is not phonetically natural
- Gurevich (2003): intervocalic spirantization occurs *in functional response* to stops that have undergone intervocalic voicing. Otherwise intervocalic voiced stops usually stay stops.
- β, ð, ɣ *exclusively* alternate with b, d, ɡ; they do not contrast with b, d, ɡ. Spirantization is thus non-neutralizing.

(31)

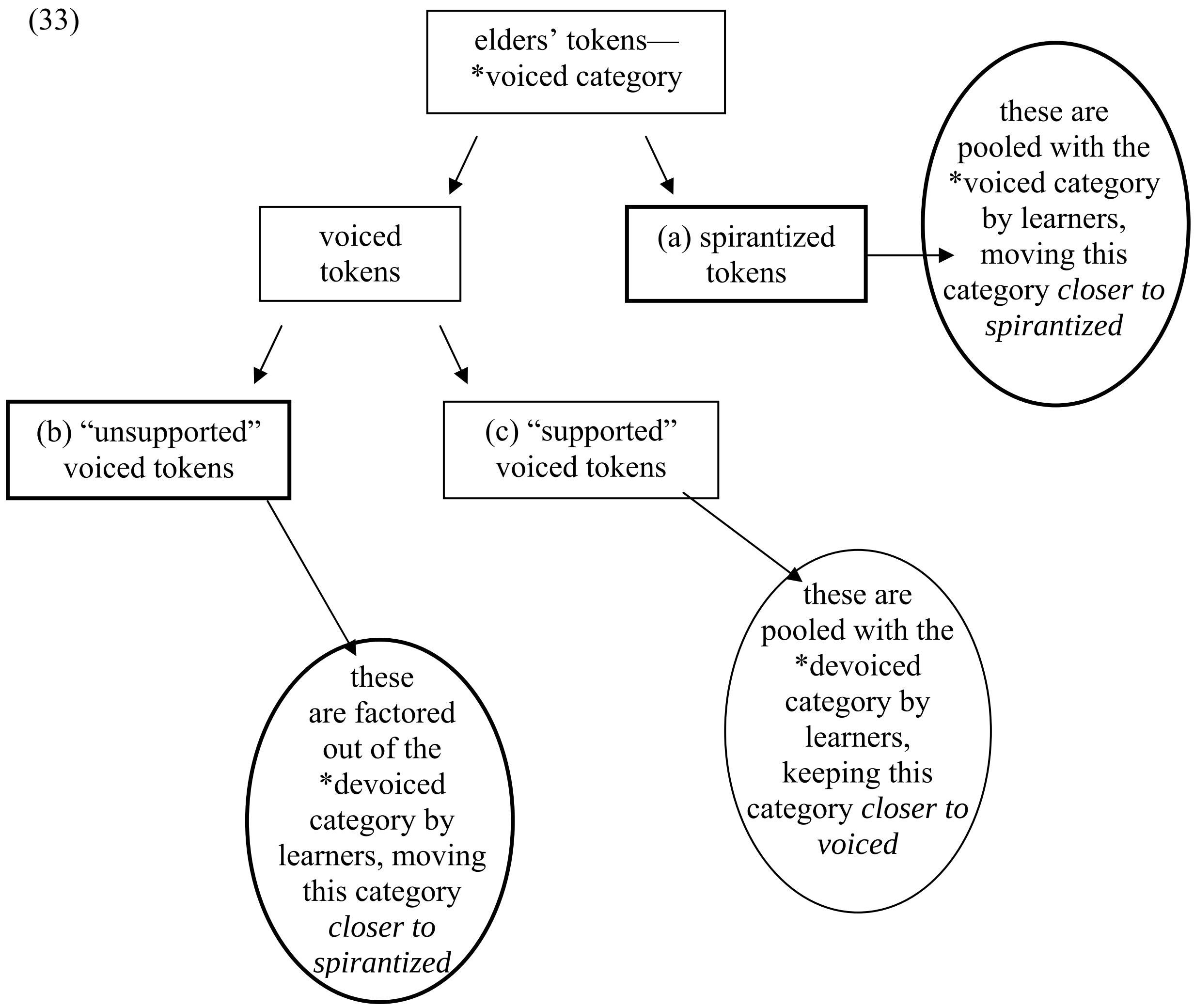


- "Supported" tokens: stray tokens that are nonetheless disambiguated with grammatical or real-world information; this provides "support" in conveying the semantic intentions of the speaker.
- "Unsupported" tokens: stray tokens that are *not* disambiguated with grammatical or real-world information; these may be miscommunicated.

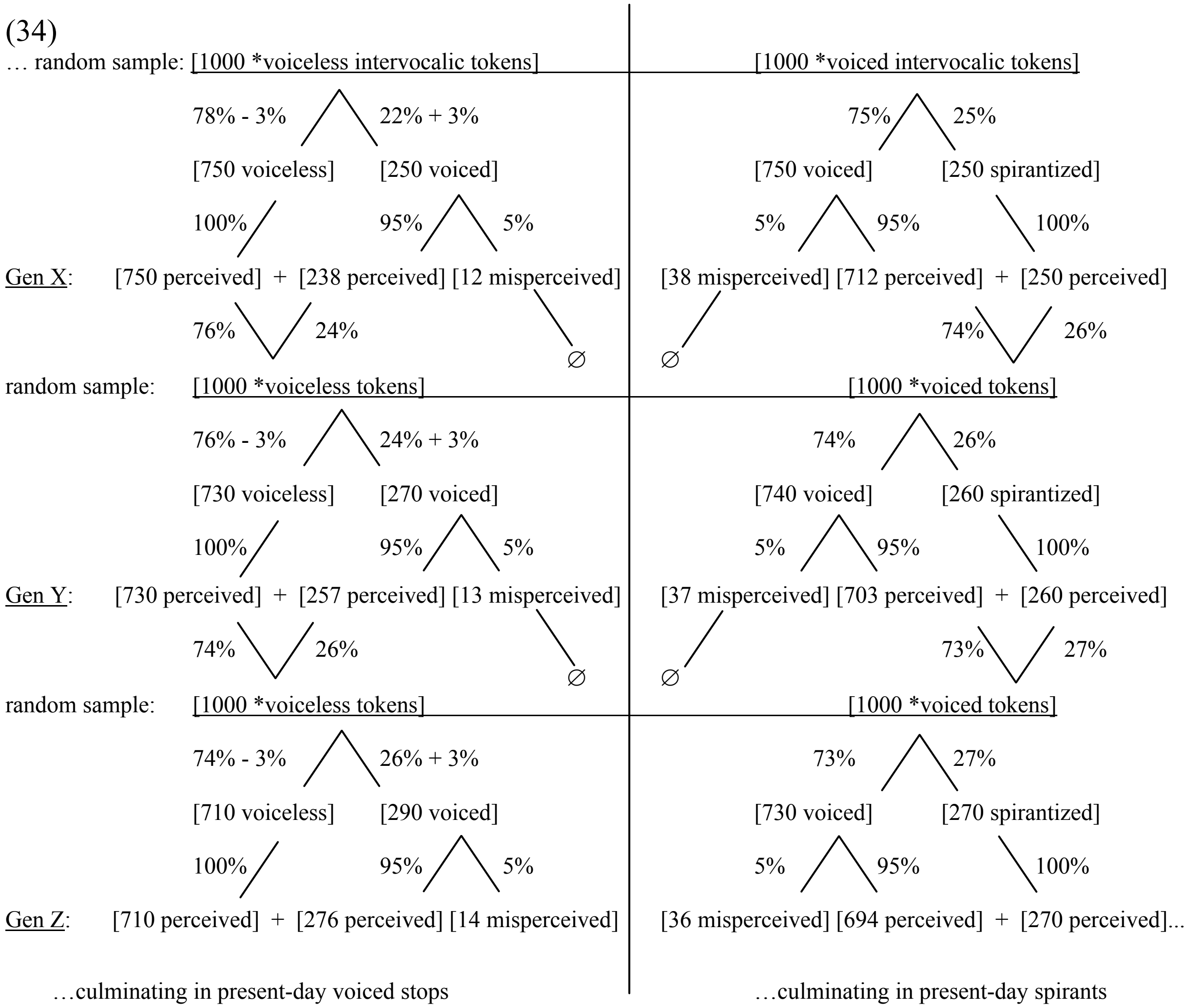
(32)


elders' tokens—
*voiceless category
(a) voiceless tokens
voiced tokens
these are pooled with the *voiceless category by learners, keeping this category *closer to voiceless*
(b) "supported" voiced tokens
(c) "unsupported" voiced tokens
these are pooled with the *voiceless category by learners, moving this category *closer to voiced*
these are factored out of the *voiceless category by learners, keeping this category *closer to voiceless*

(33)


elders' tokens—
*voiced category
voiced tokens
(a) spirantized tokens
these are pooled with the *voiced category by learners, moving this category *closer to spirantized*
(b) "unsupported" voiced tokens
(c) "supported" voiced tokens
these are pooled with the *devoiced category by learners, keeping this category *closer to voiced*
these are factored out of the *devoiced category by learners, moving this category *closer to spirantized*

(34)



- Of course, synchronic neutralizations and diachronic mergers are commonplace. However, the overwhelming tendency is for contrasts to neutralize in contexts with insufficient opportunity for the salient expression of acoustic cues, for example, before another consonant and/or under stresslessness, where consonants typically lack their all-important release cues. But when the opportunity for cue expression is greater, neutralization is much less common.
- Moreover, neutralization by itself is not counter-functional. What matters is the extent to which neutralization induces homophony. I'm investigating this issue now (Silverman, in prep.)

Points for discussion:

- In phonology, Monday morning quarter-backing is fine!
- The tools of the present approach open a window to new generalizations that could not be discovered through solely synchronic means, nor can a synchronic account offer explanations for the observed patterns.

References

Antilla, Raimo 1972 *An Introduction to Historical and Comparative Linguistics*. New York, MacMillan.

Barry, Martin and Ryad Teifour 1999 Temporal patterns in Arabic voicing assimilation. Proceedings of the XIVth International Congress of Phonetic Sciences. Vo.3: 2429-2432.

Bell-Berti, Fredericka, and Katherine S. Harris 1979 Anticipatory coarticulation: some implications from a study of lip-rounding. *Journal of the Acoustical Society of America* 65: 1268-1270.

Bell-Berti, Fredericka, and Katherine S. Harris 1982 Temporal patterns of coarticulation: Lip rounding. *Journal of the Acoustical Society of America* 71, 449–454.

Briggs, Elinor 1961. *Mitla Zapotec grammar*. Instituto Linguistico de Verano, Mexico.

Burton, Martha W. and Karen E. Robblee 1997 A phonetic analysis of voicing assimilation in Russian. *Journal of Phonetics* 25: 97-114.

Bybee, Joan 2001 *Phonology and Language Use*. Cambridge Studies in Linguistics 94, Cambridge University Press.

Cahill, Michael 1999. *Aspects of the morphology and phonology of Kɔnni.* Ph.D. dissertation, The Ohio State University.

Charles-Luce, Jan 1993 The effects of semantic content on voicing neutralization. *Phonetica* 50: 28-43.

Chomsky, Noam and Morris Halle 1968 *The Sound Pattern of English*. New York, Harper and Row.

Cohn, Abigail 1990 Phonetic and phonological rules of nasalization. Ph.D. dissertation, UCLA.

Cope, Anthony T. 1960. Zulu tonology. *Afrika und Übersee* XLIII: 190-200.

Cope, Anthony T. 1966. *Zulu phonology, tonology and grammar*. Ph.D. dissertation, University of Natal.

Croft, William 2000 *Explaining Language Change. An Evolutionary Approach*. Harlow, England: Pearson Education.

Fant, Lars. 1984. Estructura informativa en español. Estudio sintáctico y entonativo. *Acta Universitatis Upsaliensis* 34, Uppsala.

Fry, Dennis B. 1947 The frequency of occurrence of speech sounds in Southern English. *Archives Néerlandaises de Phonétique Experimentales* 20.

Gallistel, Randy 1990 *The Organization of Learning*. Cambridge MA, MIT Press.

Gandour, Jack. 1977. On the interaction between tone and vowel length: Evidence from Thai Dialects. *Phonetica* 34: 54-65.

Gardner, Richard, and William R. Merrifield. 1990. Quiotepec Chinantec tone. *Syllables, tone, and verb paradigms*. Studies in Chinantec languages v.4., ed. by William R. Merrifield and Calvin R. Rensch: 91-106. Dallas: Summer Institute of Linguistics

Gluck, Mark A. and Gordon H. Bower 1988 Evaluating an adaptive network model of human learning. *Journal of Memory and Language*. 27: 166-195.

Goldinger, Stephen D. 1997 Words and voices: perception and production in an episodic lexicon. In: Keith Johnson and John W. Mullennix (eds.), *Talker variability in speech processing*. San Diego: Academic Press. 33-56.

Goldinger, Stephen D. 1998 Echoes of echoes? An episodic theory of lexical access. *Psychological Review* 105.2: 251-271.

Grimes, Barbara F. 2003 *Ethnologue: Languages of the World,* 14th Edition. Dallas: SIL International.

Gudschinsky, Sarah C. 1959 *Proto-Popotecan: A Comparative Study of Popolocan and Mixtecan*. Indiana University Research Center in Anthropology, Folklore and Linguistics Memoir, 15. Bloomington: Indiana University.

Gurevich, Naomi 2003 Functional Consequences of Certain Phonetically Conditioned Sound Changes. Ph.D. dissertation, University of Illinois.

Harper, D.G.C. 1982 Comparative foraging in mallards: ideal free ducks. *Animal Behaviour* 30: 575-584.

Herrera Z., Esther. 2000. Amuzgo and Zapotec: two more cases of laryngeally complex languages. Anthropologcal Linguistics 42.4: 545-563.

Hockett, Charles F. 1968 *The State of the Art*. Janua Linguarum. Series minor number 73. The Hague: Mouton.

Hollenbach, Barbara E. 1977 Phonetic versus phonemic correspondence in two Trique dialects. In: W.R. Merrifield (ed.), *Studies in Otomanguean Phonology*. Dallas: Summer Institute of Linguistics.

Hollenbach, Barbara E. 1984. The phonology and morphology of tone and laryngeals in Copala Trique. Ph.D. dissertation, University of Arizona.

Holsinger, David J. 1998. Tone and ballistic stress in Ojitlán Chinantec. Manuscript, University of Wisconsin-Madison.

Hombert, Jean-Marie 1978 Consonant types, vowel quality, and tone. In: Victoria Fromkin (ed.), *Tone: a Linguistic Survey*. New York: Academic Press. 77-111.

Hudson, Carla L., & Newport, Elissa L. (1999). "Creolization: Could adults really have done it all?", In Annabel Greenhill, Heather Littlefield, and Cheryl Tano, editors, Proceedings of the Boston University Conference on Language Development, 23. Somerville, MA: Cascadilla Press. 265-276.

Jamieson, Allan R. 1977. Chiquihuitlan Mazatec phonology. Studies in Otomanguean phonology, ed. by William R. Merrifield: 93-105. Summer Institute of Linguistics, Publication 54.

Janda, Richard D., and Brian D. Joseph 2001 Reconsidering the canons of sound change: towards a Big Bang theory. Manuscript of paper presented at the International Conference on Historical Linguistics, Melbourne.

Keller, Rudi 1990/1994 *On Language Change: The Invisible Hand in Language*. London: Routledge.

Khumalo, J.S.M. 1981. Zulu tonology, part 1. *African Studies* 40: 53-130.

Kim, Sahyang, and Heriberto Avelino. To appear. An intonational study of focus and word order variation in Mexican Spanish. *La tonía: dimensiones fonéticas y fonológicas*, ed. by Esther Herrera and Pedro Martín Butragueño: El Colegio de Mexico.

Kingston, John (to appear) Keeping and losing contrasts. *Proceedings of the 28th Annual Meeting of the Berkeley Linguistics Society*.

Kingston, John, and Randy L. Diehl 1994 Phonetic knowledge, *Language*, 70: 419-454.

Kisseberth, Charles. 1984. Digo tonology. *Autosegmental Studies in Bantu Tone*. ed. by G.N. Clements and J. A. Goldsmith: 105-182. Dordrecht, Holland: Foris.

Kruschke, John K. 1992 ALCOVE: an exemplar-based connectionist model of category learning. *Psychological Review* 99.1: 22.44.

Kurowski, Kathleen, and Blumstein, Sheila E. 1984 Perceptual integration of the murmur and formant transitions for place of articulation in nasal consonants, *Journal of the Acoustical Society of America* 76: 383-390.

Labov, William 1994 *Principles of Linguistic Change, Internal Factors*. Oxford: Blackwell.

Lehiste, Ilse, and P. Ivic. 1986. *Word and sentence prosody in Serbocroation*. Cambridge: MIT Press.

Liberman, Mark (this volume) Simple models for emergence of a shared vocabulary.

Lombardi, Linda 1994 *Laryngeal Features and Laryngeal Neutralization*. New York: Garland.

Longacre, Robert E. 1957 Proto-Mixtecan. *International Journal of American Linguistics* 23.4.III. Indiana University Research Center in Anthropology, Folklore and Linguistics. Bloomington: Indiana University.

Longacre, Robert E. 1962 Amplification of Gudschinsky's Proto-Popolocan-Mixtecan. *International Journal of American Linguistics* 28: 227-242.

Longacre, Robert E., and René Millon 1961 Proto-Mixtecan and Proto-Amuzgo-Mixtecan Vocabularies: A Preliminary Cultural Analysis. *Anthropological Linguistics* 4.3: 1-44.

Lotto, Andrew 2000 Language acquisition as complex category formation. *Phonetica* 57: 189-196.

Manuel, Sharon 1990 The role of contrast in limiting vowel-to-vowel coarticulation in different languages. *Journal of the Acoustical Society of America*, 88: 1286-1298.

Manuel, Sharon 1999 Cross-language studies: relating language-particular coarticulation patterns to other language-particular facts. In: William J. Hardcastle and Nigel Hewlett (eds.), *Coarticulation: Theory, Data and Techniques*, pp.179-198. Cambridge, UK: Cambridge University Press.

Martinet, André 1975, published 1988 The internal conditioning of phonological changes. *La Linguistique* 24.2: 17-26.

Navarro-Tomás, Tomás. 1944. *Manuel de entonación española*. New York: Hispanic Institute in the United States.

Nosofsky, Robert M. 1986 Attention, similarity, and the identification-categorization relationship. *Journal of Experimental Psychology: General* 115: 39-57.

Nosofsky, Robert M. 1988 Exemplar-based accounts of relations between classification, recognition, and typicality. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 14: 700-708.

Ohala, John J. 1978. Production of tone. *Tone: A linguistic survey*, ed. by Victoria A. Fromkin: 5-39. Academic Press, New York.

Ohala, John J. 1981 The listener as a source of sound change, Papers from a Parasession on Language and Behavior, Chicago Linguistics Society. 178-203.

Ohala, John J. 1989 Sound change is drawn from a pool of synchronic variation. In: Leiv E. Breivik and Ernst H. Jahr (eds.), *Language Change: Contributions to the Study of its Causes*. Mouton de Gruyter, Berlin. 173-198.

Ohala, John J., and William G. Ewan. 1973. Speed of Pitch Change, Abstract, *Journal of the Acoustical Society of America* 53: 345.

Öhman, Sven E.G. 1966 Coarticulation in VCV utterances: spectrographic measurements. *Journal of the Acoustical Society of America* 39: 151-168.

Pace, Wanda Jane. 1990. Comaltepec Chinantec Verb Inflection. ***Syllables, Tone, and Verb Paradigms.*** Studies in Chinantec Languages v.4, ed. by WilliamR. Merrifield and Calvin R. Rensch: 21-62. Dallas: Summer Institute of Linguistics.

Paster, Mary 1999. *Issues in the tonology of Gã*. Senior honors thesis, The Ohio State University.

Paul, Hermann 1886 *Principles of the History of Language* (translated from 2nd edition by H.A. Strong, 1970). College Park: McGroth Publishing Company.

Pierrehumbert, Janet B. 1980 The phonology and phonetics of English intonation. Ph.D. dissertation, MIT.

Pierrehumbert, Janet B. 1994 Knowledge of variation. Papers from the Parasession on Variation, 30th Meeting of the Chicago Linguistics Society, Chicago Linguistics Society, 232-256.

Pierrehumbert, Janet B. 1999 What people know about sounds of language. *Studies in the Linguistic Sciences* 29.2: 111-120.

Pierrehumbert, Janet B. 2001a Stochastic phonology. *GLOT* 5.6: 1-13.

Pierrehumbert, Janet B. 2001b Exemplar dynamics: word frequency, lenition, and contrast. In: Bybee, Joan and Paul Hopper (eds.), *Frequency* and the Emergence of Linguistic Structure. Amsterdam: John Benjamins.

Poplack, Shana. (1980a). "The notion of the plural in Puerto Rican Spanish: competing constraints on (s) deletion", in William Labov, editor, Locating Language in Time and Space. New York: Academic Press. 55-67.

Poplack, Shana. (1980b) "Deletion and disambiguation in Puerto Rican Spanish", Language 56.2: 371-385.

Port, Robert and Penny Crawford 1989 Incomplete neutralization and pragmatics in German. Journal of Phonetics 17.4.257-282.

Port, Robert F. and Michael L. O'Dell 1985 Neutralization of syllable-final voicing in German. Journal of Phonetics 13.455-471.

Preston, M.S., and G. Yeni-Komshian 1967a Studies on the development of stop consonants produced during the second year of life, Annual Report, Neurocommunications Laboratory, Johns Hopkins University School of Medicine 3: 211-222.

Preston, M.S., G. Yeni-Komshian, and R.E. Stark 1967b Voicing in initial stop consonants produced by children in the prelinguistic period from different language communities, Annual Report, Neurocommunications Laboratory, Johns Hopkins University School of Medicine 2: 305-323.

Prieto, Pilar, Jan van Santen, and Julia Hirschberg. 1995. Tonal alignment patterns in Spanish. *Journal of Phonetics* 23: 429-451.

Pulleyblank, Douglas 1986. *Tone in lexical phonology*. D. Reidel Publishing Company, Kluwer Academic Publishers Group. Dordrecht: The Netherlands.

Recasens, Daniel 1983 Place Cues for Nasal Consonants with Special Reference to Catalan, *Journal of the Acoustical Society of America* 73.4: 1346-1353.

Rensch, Calvin R. 1968. *Proto Chinantec phonology*. Papeles de la Chinantla VI. Seria Cientifica 10. Museo Nacional de Antropologia, Mexico.

Rensch, Calvin R. 1976. *Comparative Otomanguean phonology*. Indiana University: Bloomington.

Rensch, Calvin R. 1989. *An etymological dictionary of the Chinantec languages*. Studies in Chinantec languages v.1. Dallas : Summer Institute of Linguistics.

Repp, Bruno H. 1986 Perception of the [m]-[n] distinction in CV syllables. *Journal of the Acoustical Society of America* 79: 1987-1999.

Robbins, Frank E. 1968. Quiotepec Chinantec grammar. Papeles de la Chinantla IV. Seria Cientifica 8. Museo Nacional de Antropologia, Mexico.

Russell, Margaret. 2000. Phonetic aspects of tone displacement in Zulu. *The Proceedings of the Chicago Linguistic Society 36*, ed. by Arika Okrent and John Boyle: 427-439. Chicago: Chicago Linguistic Society.

Silverman, Daniel 1993 Labiality in Mixtecan—a unified treatment. In: Daniel Silverman and Robert Kirchner (eds.), *UCLA Occasional Papers in Linguistics* 13: 109-123.

Silverman, Daniel, Barbara Blankenship, Paul Kirk, and Peter Ladefoged 1995. "Phonetic Structures in Jalapa Mazatec," Anthropological Linguistics 37.1: 70-88.

Silverman, Daniel. 1995. *Phasing and recoverability*. Ph.D. dissertation, UCLA. Published 1997, Outstanding dissertations in linguistics. New York: Garland.

Silverman, Daniel. 1997. Tone sandhi in Comaltepec Chinantec. *Language* 73.3: 473-492.

Silverman, Daniel. 2000. Hypotheses concerning the phonetic and functional origins of tone displacement in Zulu. *Studies in African Linguistics* 29.2: 3-32.

Silverman, Daniel. 2004. Why Comaltepec Chinantec is not different. La tonía: dimensiones fonéticas y fonológicas, ed. by Esther Herrera and

Pedro Martín Butragueño. El Colegio de Mexico.
Silverman, Daniel. 2005 "Phonetics and function in diachronic conflict: the case of rising tones," Proceedings of CLS 39. Chicago: Chicago Linguistic Society.
Silverman, Daniel. 2006. A Critical Introduction to Phonology: Of Sound, Mind, and Body. London: Continuum.
Silverman, Daniel. 2006. "The diachrony of labiality in Trique, and the functional relevance of gradience and variation," in Louis M. Goldstein, Douglas H. Whalen, and Catherine T. Best, eds., Papers in Laboratory Phonology VIII, Mouton de Gruyter.
Silverman, Daniel (in prep.) Neutralization and anti-homophony in Korean.
Steels, Luc 2000 Language as a complex adaptive system. In: Marc Schoenauer, Kalyanmoy Deb, Guenter Rudolph, Xin Yao, Evelyne Lutton, Juan Julian Merelo, Hans-Paul Schwefel (eds.), Lecture Notes on Computer Science. Parallel Problem Solving from Nature. PPSN-VI. 17-26.
Sundberg, Johan 1979 Maximum speed of pitch changes in singers and untrained subjects. Journal of Phonetics 7.2: 71-79.
Sundberg, Johan. 1973. Data on maximum speed of pitch changes. Quarterly Progress and Status Reports, Speech Transmission Laboratory, Stockholm, Sweden 4: 39-47.
Thorsen, Oluf M. 1966 Voice assimilation of stop consonants and fricatives in French and its relationship to sound duration and intra-oral air pressure. *Annual Report of the Institute of Phonetics*, University of Copenhagen 5: 1-39.
Toft, Zoe, and Wouter Jansen 2003 Hungarian VA non-categorically speaking. Presentation at the 11th Manchester Phonology Meeting.
Traill, A., Khumalo, J., and P. Fridjhon. 1987. Depressing facts about Zulu. *African Studies* 46: 255-274
Xu Yi, and Q. Emily Wang. 2001. Pitch targets and their realization: evidence from Mandarin Chinese. *Speech Communication* 33: 319-337.
Xu, Yi 1997 Contextual tonal variation in Mandarin. *Journal of Phonetics* 25: 61-83.
Yip, Moira. 2002. *Tone*. Cambridge University Press.
Yu, Alan. To appear. Contour tone induced lengthening in Cantonese. *Proceedings of the 15th International Congress of Phonetic Sciences*. Barcelona.
Zhang Jie 2001 Non-contrastive features and categorical patterning in Chinese diminutive suffixation—MAX[F] or IDENT[F]? *Phonology* 17.3: 427-478.
Zhang, Jie. 2001. *The effects of duration and sonority on contour tone distribution—typological survey and formal analysis.* Ph.D. dissertation, UCLA. Published 2001, Outstanding dissertations in linguistics. New York: Garland.