Acoustic dispersion, and the functional relevance of speech variation

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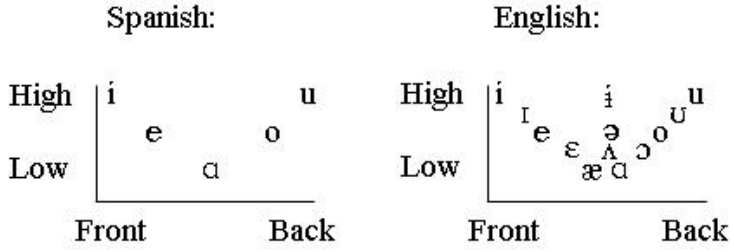
> *"The history of life is not necessarily progressive; it certainly is not predictable. The earth's creatures have evolved through a series of contingent and fortuitous events."*
> -Stephen Jay Gould
>
> "*The history of phonological systems is not necessarily progressive; it certainly is not predictable. The sounds of languages have evolved through a series of contingent and fortuitous events."*
> - Joe Schmoe

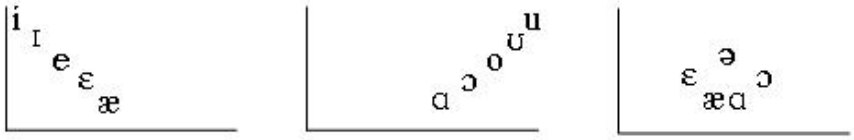
1. SETTING THE THEORETICAL AND METHODOLOGICAL SCENE

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

1. This looks familiar:



2. But this is never seen:



Cognitive *Urge*:

- 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.

Speakers' *Choice*:

- Kingston and Diehl (1994): Speakers choose different pronunciations of a phoneme in order to optimize conveying the contrast in each context that it occurs. Kingston (2002): "Speakers must be altruists."

Grammatical *Constraint*:

- 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])."
- Flemming (1995, 2001): Grammatically active constraints to maximize contrastiveness with minimal articulatory effort (cf. Lindblom's H&H theory).

- I propose shifting the locus of the mechanism
  -from **speaker** to **listener**
  -from the **synchronic** to the **diachronic**
  -from the **teleological** to the **evolutionary**
  -from **design** to **emergence**

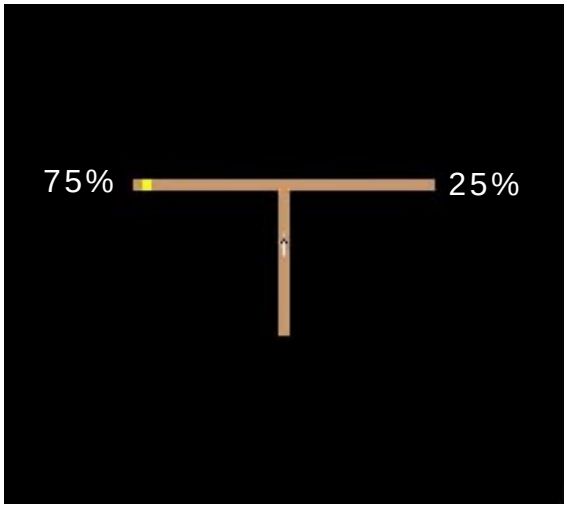
  →*Phonetic* Pressures
  →*Functional* Pressures
  →Their Diachronic Interaction

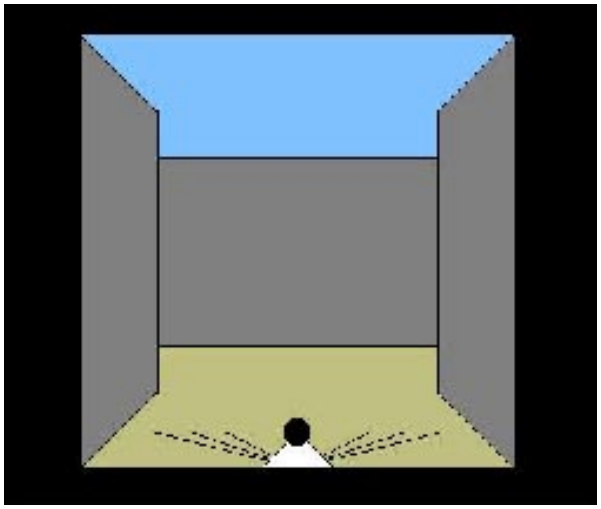
- This should look very familiar to you, as it is directly inspired by Ohala.
- Acoustic dispersion is a consequence of the communicative success or failure of the word variants that we use. Successful speech propagates; today's spontaneous, unplanned innovation may become tomorrow's new norm.

TOOLS OF THE TRADE:

PROBABILITY MATCHING

- Probability matching in lower animals (Gallistel 1990 [for animal learning], Labov 1994 [as applied to language])





- 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 (61.5% vs 75%; .75 x .75 + .25 x .25 vs 1.0 x .75 + 0 x .25).
- 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 1979, 1980a,b, 1981; *many* examples in Labov 1994), and in laboratory settings (Hudson and Newport 1999).
- Labov (1994:583): "…much synchronic variation is a residue of historical processes, rather than the immediate product of linguistic or physiological principles."
- Upshot: *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 (again, Labov 1994)

EXEMPLAR THEORY

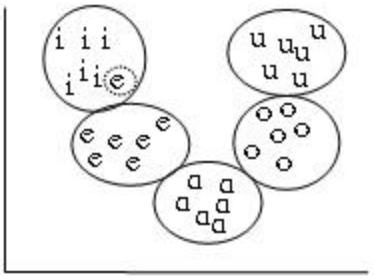
- Perceptual categories are defined as the set of all experienced instances of the category, such that variation among tokens actually contributes to the categorical properties themselves (e.g. Nosofsky, 1986,8, Johnson 1997).
- Lexical entries consist of clouds of exemplars.
- One generation's variation 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:

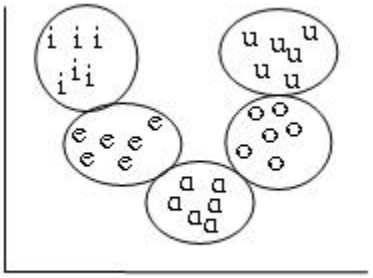


- Perception is never perfect: this token could be misperceived by listeners, or perhaps ignored.

- Ambiguous tokens are poor exemplars, and so may be 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.
- Strange as it seems, as a consequence of misperception, 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…

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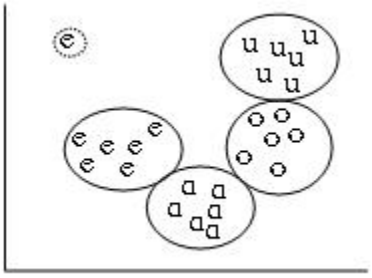
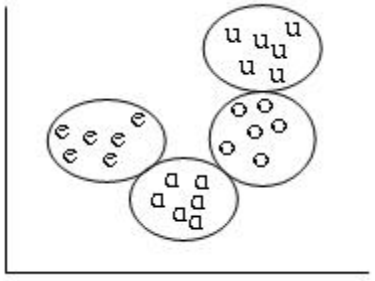
Vowel production:



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

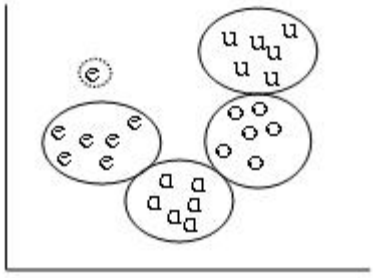
(6)

Vowel perception:



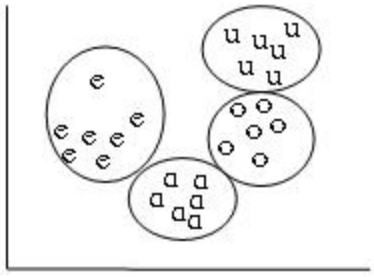
- But a *mild* stray…
  (7)

Vowel production:



- …is better separated from other categories, and may be communicated successfully.
  (8)

Vowel perception:



- In time, the elements may come to disperse themselves, availing themselves of the entirety of the acoustic space.
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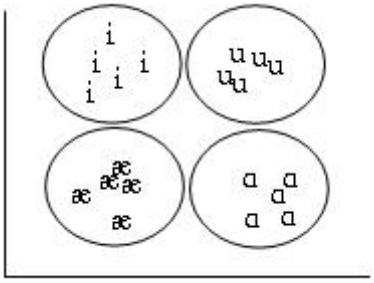
Newly evolved system:



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, Silverman 2005).
- High tones spread rightward from Low-High syllables (Pace 1990, Silverman 1995,7, 2006)

(10)

non-sandhi context:		sandhi context:	gloss:
kwa˧˥	to:˩˧	kwa˧˥ to:˧˥	give a banana
kwa˧˥	ŋɨh˩˧	kwa˧˥ ŋɨh˧˥	give a chayote
kwa˧˥	ku:˧˨	kwa˧˥ ku:˧˩	give money
kwa˧˥	^{n}dʒu:˧˨	kwa˧˥ ^{n}dʒu:˧˩	give a jug

A very significant aspect of this pattern: This alternation never neutralizes contrasts; all outputs are allophonic. Bolded values are found *only* in the sandhi contexts.

(11)

L	M	H	LM	LH	**HL**	**HM**	**MH**	gloss:
[to:˩˧]					[to:˧˥]			banana
	[ku:˧˨]					[ku:˧˩]		money
		[li˧]						flower
			[ki˩˥]					garbage
				[bʌʔ˩˥]			[bʌʔ˧˥]	ball

→Phonetic Pressures:

- Pitch rises take longer to implement than do pitch falls (much discussion: Ohala 1979, Sundberg 1979, Ladd, Mennen and Schepman 2000, Xu 1998, 2001, Xu and Sun 2002)

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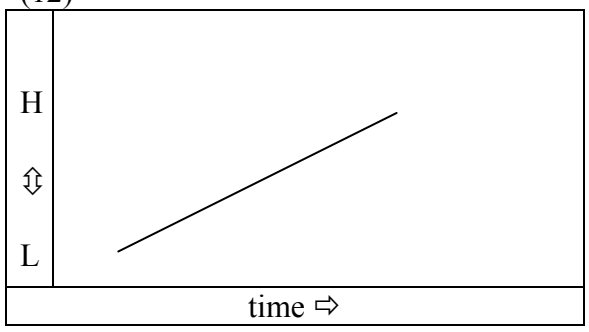
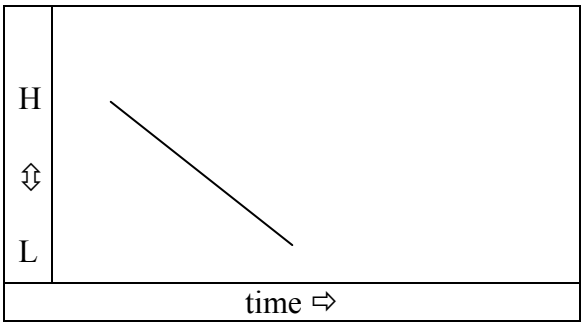
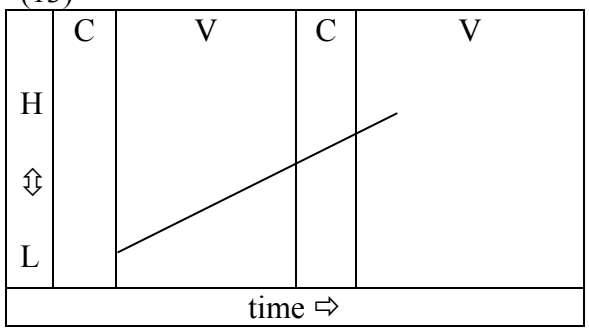
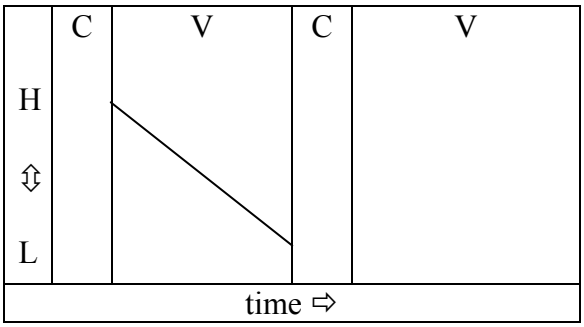




- "...[S]ince falling tones can be produced faster than rising tones...they might be less likely to 'spill over' onto the next syllable." (Ohala 1978:31)

(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, thus running the risk of neutralizing with LM)

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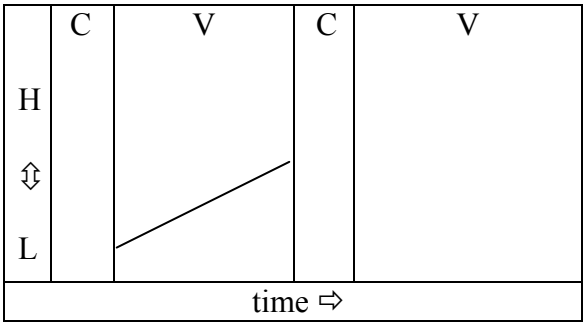

- Remember: the outputs of tone sandhi are exclusively allophonic, never neutralizing.
- Spreading the tone increases the likelihood that all contrastive values are effectively transmitted, hence increasing the likelihood that the *semantic intent* of the speaker is correctly transmitted.
- A clear reception of the semantic intentions of the speaker increases the likelihood that speech tokens are pooled in their intended categories
- Due to probability matching, these tokens are now more likely *produced* as listeners become speakers.

→Diachronic pressures:

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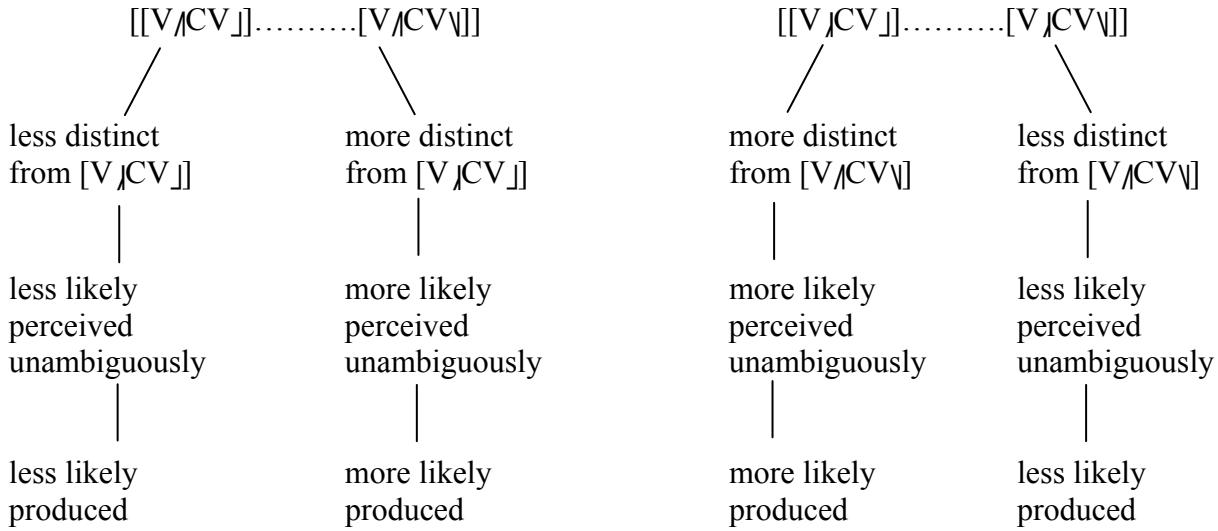


- Physical properties of the speech mechanism—phonetic factors—may induce a delay in achieving higher pitch in the context of preceding lower pitch.
- But independent functional factors may induce the conventionalization of high tone spread. As LH tones are less likely to neutralize upon spreading, displaced 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.
- NOTE: There is no teleology here, *contra* e.g. Steriade (2001), who expresses concern that acoustic confusion (à la Ohala) should not favor one sort of change over others.
- Instead, despite (or because of) confusion, "better" tokens will survive, be reproduced, and come to flourish.

Dissimilar languages possess similar patterns

- The specifics of the pattern may be influenced by functional pressures

- Mbui Bamileke (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 , bəsə́ŋ	lɔ̀ɔ̀ bə́sə́ŋ	look for the birds
lɔ̀ɔ́ , tì̀è	lɔ̀ɔ̀ tí̀è	look for the pot

lɔ̀ɔ́ , sáŋ lɔ̀ɔ̀ sáŋ look for the bird

- Quiotepec Chinantec (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)

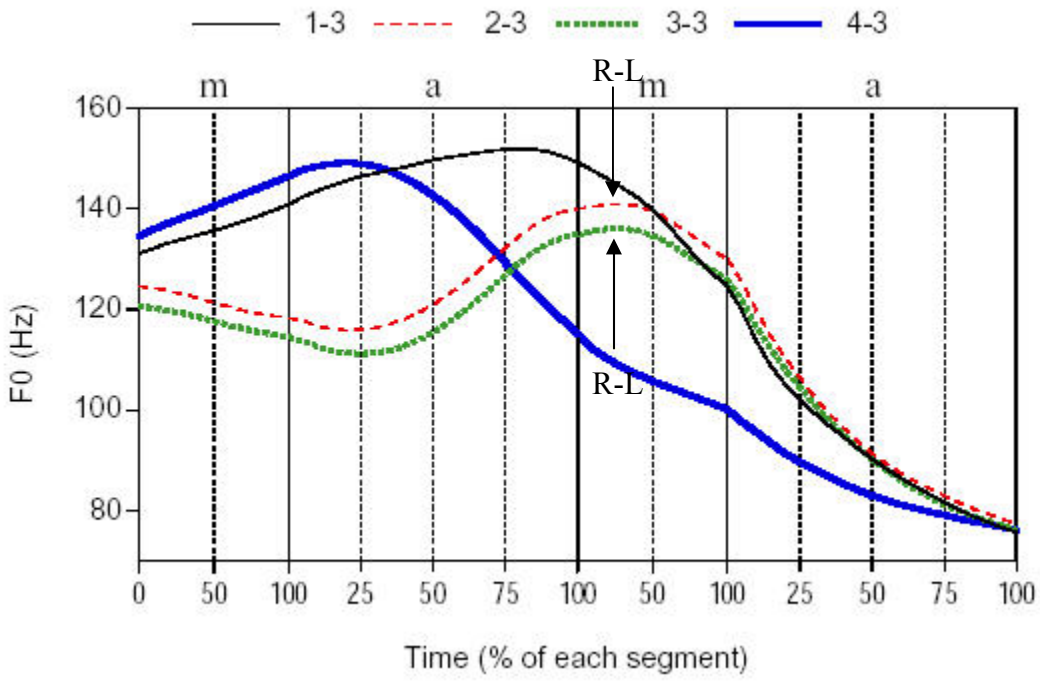
(17)

non-sandhi context:		sandhi context:	gloss:
k^{w}ó˥	tũ˧	k^{w}ó˥ tũ˥	give (me) two
cý:˥	t^{j}ý˩	cý:˥ t^{j}ý˥	good earthen jar
sí:˩	d^{j}á˧	sí:˩ d^{j}á˥	shave down ten
ʃý?˩	t^{j}új˧	ʃý?˩ t^{j}új˥	good armadillo
ʃý?˩	bõ˧	ʃý?˩ bõ˥	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



- Beijing possesses a crowded tone system (in terms of vowel-to-tone affiliation); genuine "spreading" is inhibited, *passively repelled*.

- When the tonal system is uncrowded, the spill-over effect may be greater. What happens here?
- Digo (Kenya) is a less crowded system, consisting of high tone words and low tone ("toneless") words: 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

- Pitch-accent languages are particularly
- 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).

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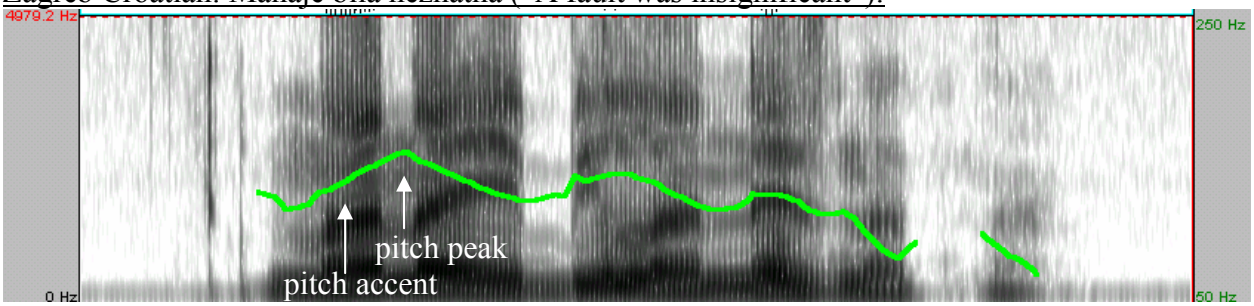
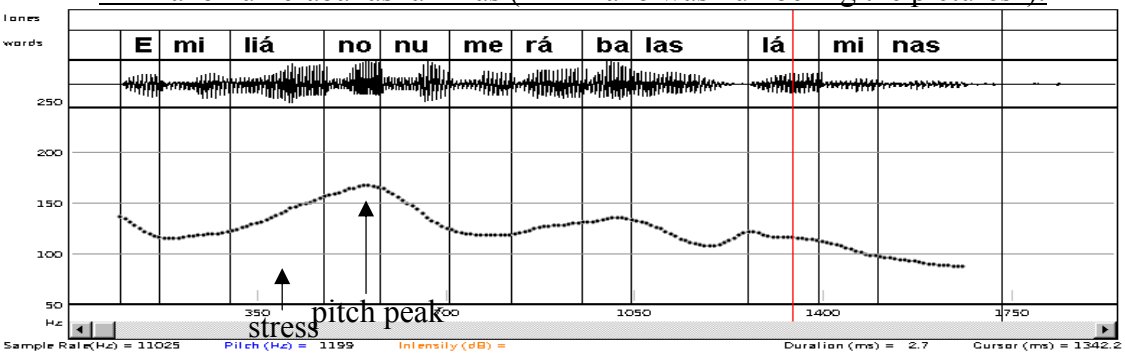
Zagreb Croatian: Manaje bila neznatna ("A fault was insignificant"):



- 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, 2007)

(22)

"morphologically-derived" rising tones on checked syllables:	gloss:	"sandhi-derived" rising tones on checked syllables:	gloss:
saː˧ kɔˈk˥˩	(a type of food)	tsʰaˈt˥˩ tsʰaːt˥˧	to brush a little
tsʊk˥˧ tsʰaˈt˥˩	a bamboo brush	pʰaˈk˥˩ pʰak˥˧	to hit a little
pɔ˧ pʰaˈk˥˩	a ball racket	kɛˈp˥˩ kɛp˥˧	to clip a little
puj˧ tɔˈk˥˩	a cup stand	tʰɔˈk˥˩ tʰɔk˥˧	to support a little
fɔŋ˧ kaˈk˥˩	a square	kaˈk˥˩ kak˥˧	to separate a little
kʌːm˧ tʃʰaˈp˥˩	a golden insert	tʃʰaˈp˥˩ tʃʰaːp˥˧	to insert a little
kʌːm˧ tsɔˈk˥˩	a golden chisel	tsɔˈk˥˩ tsɔk˥˨	to chisel a little
kɛj˧ jiˈp˥˩	propeller	tiˈp˥˩ tip˥˨	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.

- So, certain variants, along any number of potential parameters, are better at conveying *contrastive* information to listeners. As a consequence of probability matching and the misperception of strays, it is these "better" variants that survive, are reproduced, and flourish.
- A single phonetic value (here, high pitch), may thus evolve in various ways, depending on the system of contrasts as a whole: (a) high pitch spread, (b) vowel lengthening, or (c) high pitch lowering.

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:

nu<u>k</u>^{w}ah	strong	du<u>k</u>^{w}a	possessed house
du<u>g</u>^{w}ah	to twist	zu<u>g</u>^{w}i	(name)
ʒu<u>g</u>^{w}a	to be twisted	du<u>g</u>^{w}e	to weep
du<u>g</u>^{w}ane	to bathe (someone)	ru<u>g</u>^{w}i	peach
ru<u>g</u>^{w}ah	hearth stones	du<u>g</u>^{w}i	together with, companion

(25)

Trique round vowel - alveolar sequences:

ru<u>n</u>e	large black beans	u<u>t</u>ah	to anoint
u<u>t</u>ʃe	to get wet	u<u>t</u>ʃi	to nurse
u<u>t</u>a	to gather	du<u>n</u>a	to leave something
g<u>un</u>ah	to run	ru<u>d</u>aʔa	stone rolling pin
ʒu<u>t</u>ʃe	hens, domestic fowl	g<u>un</u>ɨ	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 articulatory 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: ↓ current form:		[ug^{w}a]		([ud^{w}a])			*uga		*uda ↓ [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.....ug̣a.....ug^{w}a]

less distinct from [uda] → less likely perceived unambiguously → less likely produced

more distinct from [uda] → more likely perceived unambiguously → more likely produced

∴ gradual move towards [ug^{w}a]

[uda.....ud̪a.....ud^{w}a]

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

less distinct from [ug$^{(w)}$a] → less likely perceived unambiguously → 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.
- 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 [ugʷɑ].
- [udɑ] and [ugʷɑ] 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	udʷa (500 Hz) 40	ugʷa (700 Hz) 17
udʷa	udʷa 812	ugʷa (200 Hz) 291	uga (300Hz) 71	uda (500 Hz) 223
uga	uga 964	uda (200 Hz) 355	udʷa (300 Hz) 43	ugʷa (500 Hz) 47
ugʷa	ugʷa 879	udʷa (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.

4. EXEMPLIFICATION: INTERVOCALIC OBSTRUENTS IN CORSICAN (AND ELSEWHERE)

- Phonetically conditioned sound changes can trigger phonological responses

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

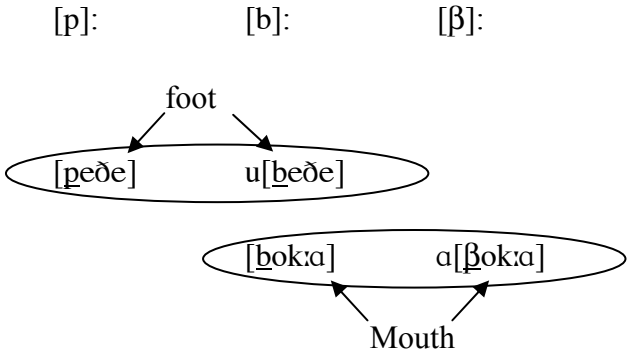
# ___ :		**V ___ V:**
Voiceless stops:	⇔	Voiced stops:
peðe ‘foot’		u beðe ‘the foot’
tengu ‘I have’		u dengu ‘I have it’
sɑkːu ‘bag’		u zɑkːu ‘the bag’
⇳		⇳
Voiced stops:	⇔	Voiced fricatives:
bokːɑ ‘mouth’		ɑ βokːɑ ‘the mouth’
dente ‘tooth’		u ðente ‘the tooth’
golɑ ‘throat’		diɣolɑ ‘of throat’

- Intervocalic voicing is phonetically natural
- Intervocalic spirantization is probably 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. (If

spirantization were so natural here, we should find spirantization of intervocalic stops far more often than we do).

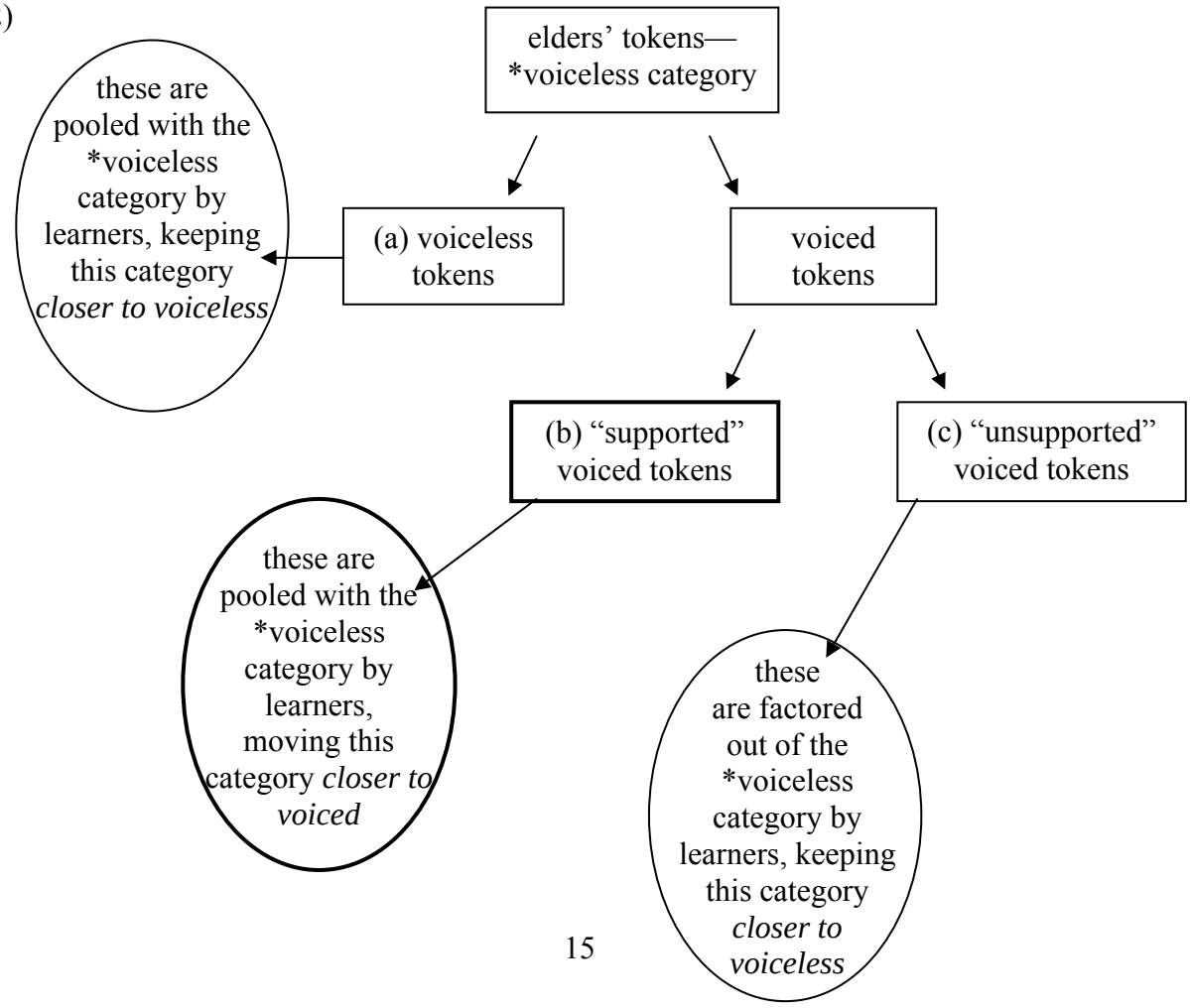
- β, ð, ɣ *exclusively* alternate with b, d, g; they do not contrast with b, d, g. Spirantization is thus non-neutralizing.

(31)

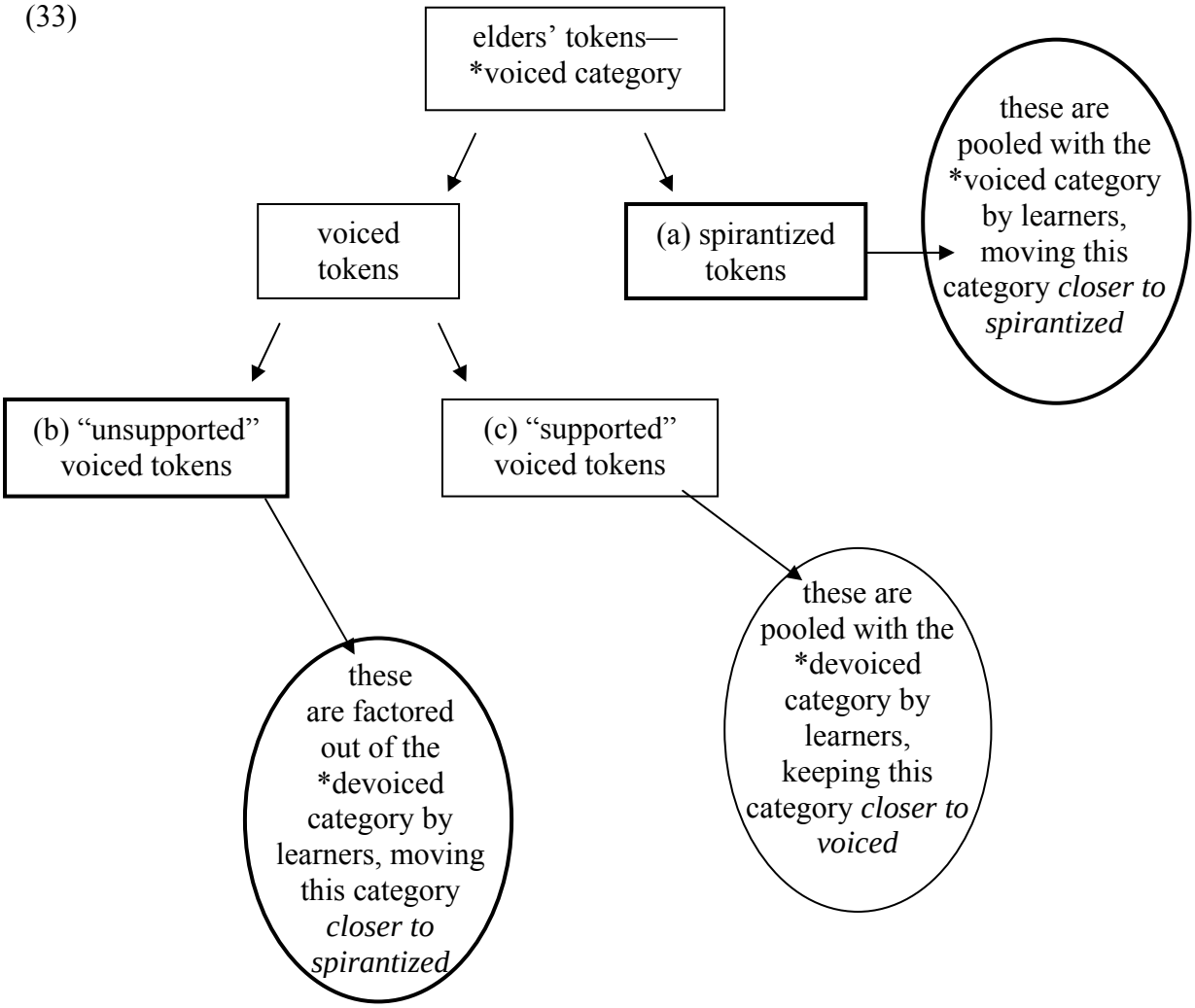


- "Supported" tokens: stray tokens that are nonetheless disambiguated with grammatical or real-world information; this provides "support" in conveying the semantic intentions of the speaker (Labov 1994).
- "Unsupported" tokens: stray tokens that are *not* disambiguated with grammatical or real-world information; these may be miscommunicated (Labov 1994).

(32)



(33)



- 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 inherently counter-functional. Ultimately, 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! After all, *"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."*
- 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.

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