The diachrony of labiality in Trique, and the functional relevance of gradience and variation

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At some point in the history of Trique, round vowels began to spread rightward across velars, eventually turning these velars into labio-velars. This spreading did not occur when the consonant was alveolar. In this study I consider the diachronic interaction of certain phonetic, cognitive, and functional forces on the Trique system which may be responsible for the asymmetrical development of this sound change, and I provide psychoacoustic experimental results which support my approach. I further propose that sound changes of the Trique sort can only be compellingly accounted for within a theory of enriched representations that incorporates the probabilistic components of language use, including (though not limited to) the distribution of variants in the acoustic/articulatory space.

One wonders whether the habit of constantly operating with graphic notations does not make some linguist(s) deaf to the gradual shifts which any painstaking observation can reveal. If one has been taught, not only that phonological systems are made up of discrete units, but also that these units are basically the same in all languages, and that even if a discrete unit may well appear under the form of different allophones, these allophones can be listed and identified, so that they, in a sense, partake in the discreteness of the phonemes, one can hardly avoid concluding that no change can take place except by means of jumps from one unit or allophone to another. Only those who know that linguistic identity does not imply physical sameness, can accept the notion that discreteness does not rule out infinite variety and be thus prepared to perceive the gradualness of phonological shifts.

André Martinet, 1975: 25

1. Introduction

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). There is an interesting distributional asymmetry in Trique which is the focus of this study. Whenever the high round vowel [u] precedes a velar consonant, a labial glide immediately follows. However, the glide is not present when the consonant that immediately follows the round vowel is alveolar. So, we find sequences like [ukwa] and [uta], but never [uka] or [utwa]. Longacre (1957) attributes this present-day asymmetry to a sound change. Historic *uka has become present-day [ukwa], for example, [zukwaha] 'fish', [rugwi] 'peach'. However, *uta has remained [uta], for example, [utah] 'annoint', not [utwah]. In this paper I suggest that Trique trans-velar labial spreading may be historically rooted in the greater likelihood of labial coarticulation in the velar context, as opposed to the alveolar context, since such coarticulation enhances the acoustic distinction between the two contrastive values. Transalveolar labial spreading cannot be similarly motivated, since labial spreading here would partially undo the increased acoustic distinction which transvelar labial spreading created. I further report the results of a psychoacoustic study which supports this phonetic account of the sound change. When subjects were asked to identify the sound sequences [uda], [udwa], [uga], and [ugwa] in various degrees of white noise, they least often confused [uda] and [ugwa] with each other. I then consider some theoretical implications of these results. First, I consider probability matching. Language users seem to learn variable linguistic patterns by calculating the perceived probability of occurrence of the variants, and largely matching this variation in their own productions (Labov 1994 pace Gallistel 1990, Liberman, 2002). I then consider the interaction of these cognitive factors with phonetic and functional influences on the sound change. Since certain variants are more likely to be perceived unambiguously - that is, since certain phonetic variants (over others) of a given word are more acoustically distinct from *other* words – then, as a consequence of probability matching, it is these variants that are more likely to be produced as listeners become speakers, and so a sound change may be set in motion. Based on the experimental results, I propose a diachronic scenario for the Trique sound change. The stability of word meaning was the decisive factor in determining the relevant phonological categories. So, for example, during the early stages of the sound change, [dugah] may have varied with [dugah], and eventually became [dugwah] 'to twist'. Since the overall meaning of the word did not change, all variants along the [q]-[q^w] continuum may have been regarded as categorially non-distinct by learners. In this sense, phonetic realizations may be categorized together as long as meaning remains stable, regardless of phonetic gradience or tokento-token phonetic variation. In other words, any emergence of phonological categories may be at least partly parasitic on perceived lexical semantic identity, rather than on the specific physical similarities or differences among variants or alternants. Finally, I consider a multiple trace or exemplar model approach to gradience and variation. I conclude that it is probably only in a theory such as multiple trace, which proposes quantitatively enriched representations, that sound changes of the Trique sort might be accounted for.

2. The diachrony - and limits - of Trique labial spreading

As mentioned, whenever the high round vowel [u] precedes a velar consonant, a labial glide immediately follows. Some examples are provided in (1). Data are from Hollenbach 1977, including forms from both the San Juan Copala dialect and closely related San Andrés Chiquihuaxtla. Words are usually disyllabic; syllables are typically CV; the relevant sequences are underlined; tones are not indicated.

(1) Trique trans-velar spreading:

n <u>uk</u> wah	strong	d <u>uk</u> wa	possessed house
d <u>ug</u> wah	to twist	z <u>ug</u> ^w i	(name)
<u>zug</u> ^w a	to be twisted	d <u>ug</u> we	to weep
d <u>ug</u> wane	to bathe (someone)	r <u>ug</u> wi	peach

The glide is not present when the consonant that immediately follows the round vowel is alveolar. In (2) are some examples of this pattern. (Throughout Mixtecan, labial consonants are quite rare, and in Trique this seems to be especially true (Silverman 1993).

(2) Trique round vowel - alveolar sequences:

r <u>un</u> e	large black beans	<u>ut</u> ah	to anoint
<u>ut∫</u> e	to get wet	<u>ut∫</u> i	to nurse
<u>ut</u> a	to gather	d <u>un</u> a	to leave something
r <u>ud</u> a?a	stone rolling pin	<u>3ut</u> ∫e	hens, domestic fowl

This asymmetry seems to be due to a sound change (Longacre 1957, 1962, Gudschinsky 1959, Longacre and Millon 1961, and Rensch 1976). Among

the root-final syllables that Longacre (1957) reconstructs for Proto-Mixtecan is *ka. This sequence largely survives in the three main branches of Mixtecan, which include Mixtec, Cuicatec, and Trique. In Mixtec, the pattern basically survives in full. In Cuicatec, both [ka] and [ku:] are found. In Trique, ka survives except when the penult possesses [u]. In this context, we now know, Trique possesses a labial glide at stop offset. Longacre states that "(The) T(rique) g^w cluster is largely a development of g in the situation u...a" (p.17). He further lists Proto-Mixtecan *ka as becoming Proto-Trique *k^wa in the context of a preceding [u]: "*ka > [...] (u)k^wa" (p.33).

The prevalence of [uk^wa] forms over [uk^w] forms with other final vowels seems due to a number of factors. *ko merged with *ka, and subsequent lexicalized compounding innovations have lead to labial spreading in the relevant contexts: *ko 'snake, lizard' became intermediate [ka] and, combining with [3u] 'animal', becomes [3uk^wa] 'snake'. This means that both *uka and any *u+ko forms became Trique [ukwa]. Among the other non-round final vowels which, in theory, could have followed *uk were *i, *i, and *e. But *ki and *ki were rare in Proto-Mixtecan, and barely survive into Trique, and *ke is not even reconstructed for Proto-Mixtecan. Regarding *a, in a few cases, including some words with [u?w_2/h], and [ugw_h], *a has raised to [e]. It has sometimes raised to [i] in the situations [aw], [a?w ?/h], and [ug^w (?)] (Longacre 1957: 44). These idiosyncratic innovations may have lead to the broader contexts of labial spreading found today, such that the u-velar-w sequence may now very sporadically precede [i] or [e] as well. Labialization is never found before [0], because CuCo forms are largely absent from the language. Hollenbach provides only two such forms, and neither possesses a velar as the second consonant ([guno] 'to hear', [uno] 'to sow'). CuC^wu is absent in Trique, perhaps because it does not make for a robust acoustic contrast with CuCu. Indeed, it is rare that a language has lexical contrasts involving C^wu and Cu (though they may be present at the post-lexical level, e.g. English "hoodoo" versus "who'd woo").

The mid round vowel [o] is largely absent in penults. Hollenbach writes that "Although all five long vowels occur in nonultimas [penults –D.S.], it is almost possible to reduce the number of contrasts in this position to three [...] /e o/ are uncommon in non-ultimas. They occur mainly when the ultima vowel is itself mid" (p.42f). Therefore, the absence of labio-velars following [o] may be a consequence of the near absence of [o] in this context, and is not due to an asymmetrical application of the spreading process itself.

Significantly, in Proto-Mixtecan, k and k^w were not contrastive in the context of a preceding round vowel (Longacre 1957). Consequently, transvelar labial spreading innovation did not induce homophony; the change was purely contrast-maintaining, indeed, contrast-enhancing.

The table in (3) breaks down CVCV sequences into sixteen logical labial classes, only seven of which are actually documented in Longacre's Trique word list (consisting of about 500 items). "Cw" represents any labial(/ized) consonant, while "Vw" represents any round vowel.

(3) Trique disyllabic root classes with respect to the distribution of labiality

$C_1 V_1 C_2 V_2$ Classes:	# o	f subclasses:
C V C V	72	
$C^{w}V C V$	6	
C V ^w C V	11	$(C_2 \text{ is never velar})$
$C V C^w V$	17	$(C_{2}$ is a plain labial in 10 subclasses, a
		labialized velar in 7)
$C V C V^w$	20	
$C^w V^w C V$	0	
$C^w V C^w V$	0	
$C^w V C V^w$	0	
$C V^w C^w V$	31	$(V_1 \text{ is always } [u]; C_2 \text{ is virtually always}$
		a labialized velar or [w]; very rarely
		[m])
$C V^w C V^w$	15	$(V_1 \text{ and } V_2 \text{ are identical in all but one})$
		entry)
$C \ V \ C^w \ V^w$	0	
$C^{w}\;V^{w}\;C^{w}\;V$	0	
$C^w V^w C V^w$	0	
$C^w V C^w V^w$	0	
$C V^w C^w V^w$	0	
$C^{w}\;V^{w}\;C^{w}\;V^{w}$	0	

Although the prevalence of words within each class is not indicated, the "totals" column lists the number of subclasses within each root class. Each subclass is different from all others in terms of at least one consonant or vowel. Vocalic length, phonation, nasality, and tone distinctions are pooled, however. The totals, along with the parenthesized commentary, convey the

strict limitations on the distribution of labiality in Trique. In particular, labial spread is only present when V_1 is [u] and C_2 is velar.

3. Phonetic underpinnings

Why should a labial glide have evolved in the *uk context? The answer I wish to pursue includes phonetic, functional, and cognitive components, which diachronically interact. Consider some phonetic facts first. The tongue and lips are independent articulators; both may be active simultaneously. In the historical context under investigation, it is reasonable to assume that the liprounding gesture characteristic of [u] may have variably perseverated into the dorsal closure characteristic of [k]: [k]. General perserveration of rounding has been documented in New York English, for example (Bell-Berti and Harris 1982). Other vocalic gestures in addition to labiality have been shown to both perseverate and anticipate in this fashion (Öhman 1966, Bell-Berti and Harris 1979, for example). Moreover, given the tongue-backing gesture required of the preceding vocoid, the distance traversed by the dorsum to implement the stop closure is comparatively short, thus increasing the likelihood of some variable rounding "spill-over". That is, given the short time frame of dorsal closure implementation, minor timing variations may lead to rather pronounced acoustic distinctions among variants. Specifically, persistence of lip-rounding through the dorsal closure may lead to the perception of a labialized velar.

This might seem like a good point of departure for the evolution of $[uk^wa]$ in Trique. Unfortunately, the proposal suffers from a fatal flaw. The problem is that certain other consonants may just as readily be produced with perseverative labiality as may [k]. Thus, for example, an alveolar stop involves a (typically rapid) tongue-tip raising gesture, which can be achieved largely independently of the dorsal backing gesture characteristic of [u]. We might thus predict little-to-no asymmetry in the diachronic comportment of *uka and, say, *uta. Yet Trique clearly has not treated these two patterns in a parallel fashion: *uta \rightarrow [ut^wa].

Instead, the spreading asymmetry may serve to enhance the acoustic distinction between the two contrastive values. Since, according to Longacre's reconstructions, *uk^w sequences were absent in the proto-language, spreading labiality across the velar *increased* the acoustic distinction between the velars and the alveolars, without inducing homophony. Accompanying trans-alveolar spreading, by contrast, would serve to *diminish* the acoustic distinction. This is suggested spectrographically in (4), where waveforms, wideband spectrograms, and formant tracks are provided for the sequences [uda], [ud^wa], [uga], and [ug^wa], spoken by a native speaker of New York English (the author).

(4) Waveforms, spectrograms, and formant tracks for the four sequences spoken in New York English.



Observe the F2 onset values after stop release in the circled regions. F2 onset values are: [uda] 1700 Hz, [ud^wa] 1200 Hz, [uga] 1500 Hz, [ug^wa] 900 Hz. Thus, [ug^wa] and [uda] are maximally distinct.

To summarize the proposal, 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. This proposed mechanism of sound change is not speaker-induced (through an effort to enhance the distinctness among contrastive elements) as has been suggested by some researchers. For example, Kingston (2002) concludes that "[S]peakers exert themselves to convey contrasts in ways that are entirely unexpected if they couldn't optimize their pronunciations to ensure that contrasts are conveyed," and that "Speakers must be altruists" (emphasis mine). Instead, I propose a listener-based account by which contrasts might be enhanced passively, evolving over generations of speakers, due to the communicative success of some tokens, and the communicative failure of others. Note especially that the labial glide has not suddenly popped out of the ether in an effort on the part of the speaker to enhance the distinction among the relevant contrastive configurations. Instead, labiality was already loitering in the neighborhood, so to speak, and was passively harnessed to play a new, functionally beneficial role.

4. Experiment

A laboratory condition may serve to recapitulate elements of the hypothesized historical scenario in "sped-up" form by introducing white noise into the speech signal, and having listeners report on their perception. Although only the author's speech was employed, subsequent investigation of three other native speakers of English revealed largely comparable F2 onset values.

4.1. Subjects and methods

The subjects for this double-blind study were 10 University of Illinois students in linguistics, all native English speakers. Sound files consisting of the four relevant phonetic sequences were digitally recorded in the Department of Linguistics' phonetics lab at a sampling rate of 22,050 Hz: [uda], [ud^wa], [uga], [ug^wa].

Each file was overlaid with four levels of white noise, with each noise level increased in amplitude from the previous level. Including a nonoise level, this resulted in a total of four continua with five noise levels each, for a total of twenty sound files. Stop closure durations for the four forms were: [uda] - 50 msec, [ud^wa] - 51 msec, [uga] - 40 msec, [ug^wa] - 54 msec. Second vowel durations from stop release (thus including the glides) were: [uda] - 210 msec, [ud^wa] - 213 msec [uga] - 213 msec, [ug^wa] - 202 msec. Pitch tracks and intensity contours were comparable across stimuli.

Using PsyScope, subjects listened with headphones in a quiet room to 1000 trials – 50 of each of the 20 sound files – in randomly generated blocks of 100, with a 2 second inter-trial interval, and untimed rests between blocks. Using the keyboard, subjects reported which sound sequence they heard ([uda], [udWa], [uga], or [ugWa]). Subjects were encouraged to guess if they were undecided.

4.2. Results

In order to eliminate any floor or ceiling effects, the no-noise condition (5% incorrect responses) and maximum-noise condition (60% incorrect responses) were not pooled. The highest total of pooled errors is 792 (26%

incorrect responses), for the [ud^wa]-[ug^wa] distinction (F2 onset difference minimal at 200 Hz), and the lowest total of pooled errors is 32 (1% incorrect responses), for the [uda]-[ug^wa] distinction (F2 onset difference maximal at 700 Hz). Overall, these results suggest that the F2 distinctions among the four sound sequences are good predictors of confusability: by and large, the more similar the F2 onset values, the more confusable; the less similar the F2 onset values, the less confusable. It further suggests that stop closure duration and second vowel duration had little effect on listeners' classifications.

A confusion matrix, also excluding the no-noise and maximum-noise conditions, is provided in (5). Correct responses are bold-boxed. Percentages reflect the number of responses out of 1500 (500 each at the middle three noise levels; not all stimuli were responded to).

perceived \rightarrow presented \checkmark	uda	ud ^w a	uga	ug ^w a
1-	1208	40	145	17
uda	81%	3%	10%	1%
1W -	223	812	71	291
udra	15%	54%	5%	19%
	355	47	964	43
uga	24%	3%	64%	3%
Wa	15	501	14	879
ugra	1%	33%	1%	59%

(5) Confusion matrix

There are two notable trends in the pattern of directional errors. First, labialized stops are more often misperceived as non-labialized (323 errors), rather than vice versa (147 errors). Second, velars are more often misperceived as alveolars (918 errors), rather than vice versa (524 errors). Both of these asymmetries might be due to a response bias induced by phoneme frequency factors. For example, according to Fry (1947), [t] occurs with more than twice the frequency of [k] in the English spoken in Southern Britain. A similar account might be offered for the pattern of correct responses. However, two subjects, to the exclusion of the other eight, quite regularly reported hearing [uda] when presented with [ud^wa]. It is not clear why these two subjects – and *only* these two subjects – responded in this fashion, but

their idiosyncratic performance might be an alternative reason for aspects of the observed pattern of errors.

In (6), the confusion matrix is re-arranged according to increasingly distinct F2 oppositions (Levels 2 through 4). Estimated absolute F2 onset differences are parenthetically noted. As presented in (6), it becomes clear that the presence versus absence of the glide is readily perceived, but confusion increases between forms which differ solely in terms of the stop's place of articulation, especially when labiality is present. The degree of confusion thus does indeed correlate well with the degree of F2 similarity.

noracived N	Level 1	Level 2	Level 3	Level 4
presented \checkmark	Correctly	Nearest F2	Mid F2	Furthest F2
	answereu			
uda	uda	uga (200 Hz)	ud ^w a (500 Hz)	ug ^w a (700 Hz)
uuu	81%	10%	3%	1%
ud ^w a	ud ^w a 54%	ug ^w a (200 Hz) 19%	uga (300 Hz) 5%	uda (500 Hz) 15%
uga	uga 64%	uda (200 Hz) 24%	ud ^w a (300 Hz) 3%	ug ^w a (500 Hz) 3%
ug ^w a	ug ^w a 59%	ud ^w a (200 Hz) 33%	uga (500 Hz) 1%	uda (700 Hz) 1%

(6) F2-based confusion matrix

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.

5. Discussion

Before embarking on a discussion of certain theoretic implications of Triquetype sound changes, I want to briefly consider a mechanism by which one sound might gradually change into another. Martinet's take on this matter, encapsulated in the quote which opens this paper, implicates the importance of the gradience and variation which are inherent in speech production: the gradual nature of some sound changes can be explained by considering the gradient and variable nature of speech production itself. Similar proposals have made, for example, by Paul (1886: 43), Hockett (1968: 83) Antilla (1972: 53) Ohala (1989), and Janda and Joseph (2001). But given this inherent gradience and variation, again, what is the actual mechanism by which they might induce sounds to change? To answer this question, I briefly turn to the foraging behavior of rats and ducks.

5.1. Probability matching

Gallistel (1990: 352) reports on a study in which 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, these 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 a higher rate of reward if they ran to the one end 100% of the time (61.5% versus 75%). Experimental variations on the rat-in-a-T-maze theme have been performed, yielding similar results. For example, in a somewhat less controlled experimental setting, Harper (1982) reports that two experimenters standing by a pond, set apart from each other some distance, threw food to ducks at two different rates. Very quickly, the ducks were able to calculate the distinct rates of feeding, and match their foraging time near each experimenter accordingly, spending more time at the location of greater payoff, and switching to the location of lesser payoff for a percentage of time that matched the lower yield. These ducks did not necessarily receive any food before matching their behavior to the probability of payoff. Rather, some were able to predict the payoff before any reward was received.

Comparable statistical calculations seem to underlie certain aspects of human linguistic behavior: even though certain variants are better than others at communicating speakers' lexical semantic content to listeners, when listeners become speakers they largely match their own variation of production to that which they perceive, including both "better" variants (more distinct from other words) and "worse" variants (less distinct from other words). (See, for example, Preston and Yeni-Komshian 1967, Poplack 1980a,b, Hudson and Newport 1999). But if listeners were able to perfectly match the probabilities

present in the speech that is produced around them, then, *ceteris paribus*, sounds would never have the opportunity to change in the proposed fashion. Rather, perfect reproduction would yield perfect diachronic stability. Since sounds do change over time, we may assume instead that listeners match their speech to their own perceptions of these ambient productions. When two different words are acoustically similar, some tokens of the one word may be misperceived as the other word, or may simply remain unanalyzed (that is, be thrown out, ignored). Since perception is demonstrably imperfect, then reproduction is imperfect as well, and so a sound change may gradually ensue. Since probability matching is based on listeners' perceptions, sound patterns may slowly take on new characteristics in the direction of the "better" - less ambiguous - tokens. (The misunderstanding of ambiguous tokens would be extremely difficult to document in a systematic way, but Labov [1994] discusses many anecdotal cases, and suggests that the phenomenon is far more prevalent than innocent language users would like to think.) Most systems of reproduction are imperfect, and in speech (re-)production, the facts of probability matching suggest that one locus of this imperfection may lie in the realm of perception. However, the mimetic abilities of speakers are imperfect as well. Due to the inherent imperfection of speech (re-)production, there will inevitably be *some* stray tokens which end up confusable with other words. Strays which are too similar to another word are more likely to be passively factored out (thrown out, ignored) because they remain uninterpreted by the listener, and thus serve to induce and maintain an acoustic buffer between one word and others. Other strays, however, might be slightly *more* distinct from other words than most tokens are. Such strays may become more prevalent in the system, due to their perceptual and consequent functional advantages: one generation's strays may evolve into a later generation's norm.

Consider how probability matching may play a role in sound changes of the Trique sort. There is inherent gradience and variation in speech production, thus [uka...uk^wa], and [uta...ut^wa] are among the possible variants. If Longacre's reconstructions are accurate, then in the proto-stages, productions leaned heavily toward [uka] and [uta]. However, stray [uka... uk^wa]-like variants rendered the [u]-velar-V sequences more distinct from their [u]-alveolar-V counterparts. Therefore, these variants were more likely communicated unambiguously to listeners. Ambiguous tokens – specifically, [ut^wa]-like variants – were sometimes miscategorized (misinterpreted as an unintended word), but also were sometimes uncategorized (simply ignored), and hence were not added to the pool of tokens over which probabilities were calculated, and so [uta] survived largely intact. That is, the variation engaged in by elders was largely matched by learners, but nonetheless, due to the greater likelihood of unambiguous perception of certain variants over others – [ukwa] over [uka]; [uta] over [utwa] – learners' calculated probabilities may have differed slightly from their elders', in that the variants which contrast more sharply with other words were more often perceived correctly, hence, in turn, more likely produced. Consequently, listeners were more likely to perceive [uk^wa] and [uta] as unambiguously belonging to different categories, and hence, as the generations proceeded, speakers were increasingly more likely to produce [ukwa] and continue to produce [uta] in their own speech, as a consequence of probability matching. It is quite likely that the very words at greatest risk of homophony – words in dense lexical neighborhoods - would lead such a shift. Indirect support of this hypothesis comes from studies by Port and Crawford (1989) and Charles-Luce (1993). Both reports find that in semantically ambiguous contexts, speakers are less likely to implement genuinely neutralized variants of potentially homophonous forms than they are in semantically unambiguous contexts. Charles-Luce writes (1993: 41), "This is not to suppose that this is conscious behavior. It may be guite automatic and learned through experience with communication," although Charles-Luce seems to give experience with speaking at least as much of a role to play as experience with listening. It is also possible that token frequency factors influence such changes as well. Certain frequent words might lead the change, only to be followed by others as the change diffuses through the lexicon (e.g. Bybee 2001).

Consider, then, an impressionistic formulation of the proposed mechanism, portrayed in (7). 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. Moreover, it is consistent with the fact that sound change is probabilistic, and not deterministic. Not every Mixtecan language underwent the sound change that Trique did. There simply exists a probability that any given sound change will take hold in any given speech community. Probabilities may be affected by, among many other factors, the language-specific system of contrasts, and the contrastive values' functional load: in Trique the introduction of labio-velars was contrast-enhancing, since spreading did not induce homophony. In some other language, a prevalence of contrastive labialized velars might very well passively induce the curtailment of such a sound change (see Öhman 1966, Manuel 1990, 1999 for suggestive synchronic evidence).

(7) Diachronic forces at work



5.2. Multiple trace theory

The speech signal is rife with phonetic detail to which listeners are demonstrably sensitive as they listen and learn, since they largely recapitulate in their own speech the very variation which they perceive. Indeed, exactly because gradience and variation are conventionalized in the observed manner, we have clear behavioral evidence that it is part of speakers' phonological knowledge. According to multiple trace theory, also known as "episodic" or "exemplar" theory (Gluck and Bower 1988, Goldinger 1997, 1998, Johnson 1997, Kruschke 1992, Nosofsky 1986, 1988, Pierrehumbert 1994, 1999, 2001a,b, Steels 2000, Bybee 2001, Lotto 2000, Wright 2003), emergent perceptual categories are defined as the set of all experienced instances of the category, such that variation across exemplars actually contributes to the categorical properties themselves. It is knowledge of – and sensitivity to – this variation that surely influenced Martinet's assertion that "discreteness does not rule out infinite variety."

With both probability matching and multiple trace theory to work with, we are now able to draw some preliminary theoretical conclusions regarding the diachrony of labial spreading in Trique. The conventions established by

speech communities betray a nuanced mastery of the phonetic variation internalized by individual speakers that is demonstrably a part of these speakers' linguistic knowledge. The exquisite articulatory control that speakers display in their productions is best evidenced by the fact that they are able to largely match the variation present in the ambient pattern. On this view, learners' articulatory talents may be harnessed largely in service to *copying* or *imitating*. not *modifying* (improving upon or otherwise) the ambient speech pattern. The facts of probability matching are thus consistent with the hypothesis that categorical phonological (phonetic) targets may not exist. Rather, consistent with multiple trace theory, the target of phonological acquisition may be the gradience and variation itself. But still, speakers' mimetic talents are not perfect. Stray tokens are inevitable, and it is the functional benefit of certain of these strays which might ultimately take hold in a system and come to permeate the lexicon. If language theorists insist on maintaining a distinction between speakers' phonetics and phonology, then we might say that genuine strays are phonetic, while all variation that is probability-matched is phonological in origin.

6. Conclusion

In this study I have employed the laboratory in an attempt to recapitulate the forces responsible for a sound change which took place in Trique. On the working assumption that some sound changes are a consequence of listeners misinterpreting the words intended by speakers, the proper laboratory conditions may reflect real-world historical patterns in compressed form. The operative assumption in the present experiment has been that 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. Given that language learners largely (though imperfectly) match the variation they perceive, the sorts of perceptual errors induced in the present study might only reflect the culmination of a slow, generation-to-generation accretion of such errors, rather than offering any major insights into the online processing of natural speech. The gradience and variation inherent in speech production may be the fodder for these sorts of sounds changes: the more distinct the variant from an acoustically similar word, the more likely that it will be interpreted correctly, and so the more likely the system will wend towards this value. In the present experiment, the least confusable forms ([uda] and [ugwa]) are exactly those which actu-

ally seem to have evolved in Trique from more confusable forms ([uda] and [uga]).

I emphasize that the proposals advanced herein should not be interpreted in teleological terms. Language is not inexorably headed toward an optimal state. Language evolution is unguided and passive, just as in the evolution of species. (See also Keller 1994, and Croft 2000 for extended discussion.) Speakers are probably no more "altruistic" than are stowaway rats on a garbage scow. Indeed, for every case of contrast-enhancing sound change (typically, as in the Trique case, found in pre-vocalic or stressed contexts, where there is greater opportunity for contrast-enhancing variation), we might encounter a case of contrast-merging sound change (typically found in pre-consonantal or stressless contexts, where there is less opportunity for contrastenhancing variation).

Finally, I note that the present psychoacoustic findings do not bear directly on the issues of phonological categorization or probability matching, since no meanings were associated with the sound sequences. Nonetheless the findings may be seen as consistent with the sorts of diachronic scenarios that are likely, given the facts of probability matching, and given the theoretical assumptions of multiple trace theory.

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References

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

Bell-Berti, Fredericka and Katherine S. Harris

- 1979 Anticipatory coarticulation: some implications from a study of liprounding. *Journal of the Acoustical Society of America* 65: 1268– 1270.
- 1982 Temporal patterns of coarticulation: Lip rounding. *Journal of the Acoustical Society of America* 71, 449–454.

Bybee, Joan

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

Charles-Luce, Jan

1993 The effects of semantic content on voicing neutralization. *Phonetica* 50: 28–43.

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.

- 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.
- 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.

Harper, D.G.C.

1982 Comparative foraging in mallards: ideal free ducks. *Animal Behaviour* 30: 575–584.

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.
- Hudson, Carla L. and Elissa Newport
 - 1999 Creolization: could adults really have done it all? In A. Greenhill et al. (eds.), *Proceedings of the 23rd Annual Boston University Conference on Language Development: Vol. 1.* Somerville, MA: Cascadilla Press.
- 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.

Kingston, John

- 2002 Keeping and losing contrasts. Presentation at the 28th Annual Meeting of the Berkeley Linguistics Society.
- Kruschke, John K.
 - 1992 ALCOVE: an exemplar-based connectionist model of category learning. *Psychological Review* 99.1: 22–44.
- Labov, William
 - 1994 *Principles of Linguistic Change, Internal Factors.* Oxford: Black-well.
- Liberman, Mark
 - 2002 Simple models for emergence of a shared vocabulary. Paper presented at Laboratory Phonology VIII. New Haven, CT.
- 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.
 - 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. 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*, 179–198. Cambridge, UK: Cambridge University Press.

Martinet, André

1975 The internal conditioning of phonological changes. Published in *La Linguistique* 24.2: 17–26 [1988].

Nosofsky, Robert M.

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

- 1981 The listener as a source of sound change. Papers from a Parasession on Language and Behavior, Chicago Linguistics Society, 178–203.
- 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, 173–198. Mouton de Gruyter, Berlin.

Öhman, Sven E.G.

1966 Coarticulation in VCV utterances: spectrographic measurements. Journal of the Acoustical Society of America 39: 151–168.

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.
- Knowledge of variation. Papers from the Parasession on Variation,
 30th Meeting of the Chicago Linguistics Society, Chicago Linguistics
 Society, 232–256.
- 1999 What people know about sounds of language. *Studies in the Linguistic Sciences* 29.2: 111–120.
- 2001a Stochastic phonology. *GLOT* 5.6: 1–13.
- 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 W. Labov (ed.), *Locating Language in Time and Space*, 55–67. New York: Academic Press.

- 1980b Deletion and disambiguation in Puerto Rican Spanish. *Language* 56 (2): 371–385.
- Preston, M.S. and G. Yeni-Komshian
 - 1967 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.

Rensch, Calvin R.

1976 *Comparative Otomanguean Phonology.* Bloomington: Indiana University.

Silverman, Daniel

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

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.

Wright, Richard

2003 Factors of lexical competition in vowel articulation. In John Local, Richard Ogden, and Rosalind Temple (eds.), *Papers in Laboratory Phonology VI*, Cambridge University Press. 75–87.