Tone Sandhi in Comaltepec Chinantec

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In Comaltepec Chinantec, a member of the Meso-American Otomanguean group, **H** tones spread rightward from **LH** syllables, except if the following tone is **LM**. A very significant fact about this tone sandhi pattern is that outputs are almost always allophonic, and almost never neutralizing. Only lexical **M** tones followed by aspiration neutralize with **H** tones in this same context. I account for both the allophonic and neutralizing patterns of Comaltepec sandhi by considering a combination physical forces--aerodynamic, articulatory, acoustic--in conjunction with the abstract functional principles of contrast maintenance and conservation of effort.

The lexical tones of Comaltepec include **L**, **M**, **H**, **LM**, **LH**. Any tonal pattern may be followed by aspiration and/or glottal checking. In (1) I present each lexical tone's realization in a sandhi environment. All data come from Anderson 1989, Anderson, Martinez, and Pace 1990, and Pace 1990.

(1)	a.	<u>Allophonic Sandhi Output</u>:		**L** → ***HL*** / **LH.**___	
		kwa$^{\mathbf{LH}}$ **hi**$^{\mathbf{L}}$	→	**kwa**$^{\mathbf{LH}}$ **hi**$^{\boldsymbol{HL}}$	give a book
		kwa$^{\mathbf{LH}}$ **toː**$^{\mathbf{L}}$	→	**kwa**$^{\mathbf{LH}}$ **toː**$^{\boldsymbol{HL}}$	give a banana
		kwa$^{\mathbf{LH}}$ **ŋɨh**$^{\mathbf{L}}$	→	**kwa**$^{\mathbf{LH}}$ **ŋɨh**$^{\boldsymbol{HL}}$	give a chayote

b. Allophonic Sandhi Output: **M → *HM* / LH.___**

kwa$^{\mathrm{LH}}$ kuː$^{\mathrm{M}}$	→	kwa$^{\mathrm{LH}}$ kuː^{HM}	give money
kwa$^{\mathrm{LH}}$ ndʒuː$^{\mathrm{M}}$	→	kwa$^{\mathrm{LH}}$ ndʒuː^{HM}	give a jug
kwa$^{\mathrm{LH}}$ ʔoː$^{\mathrm{M}}$	→	kwa$^{\mathrm{LH}}$ ʔoː^{HM}	give papaya

c. Neutralizing Sandhi Output: **Mh → *H*h / LH.___**

kwa$^{\mathrm{LH}}$ tũh$^{\mathrm{M}}$	→	kwa$^{\mathrm{LH}}$ tũh^{H}	give two
kwa$^{\mathrm{LH}}$ ŋgeːh$^{\mathrm{M}}$	→	kwa$^{\mathrm{LH}}$ ŋgeːh^{H}	give twenty
kwa$^{\mathrm{LH}}$ kjaʔʂ$^{\mathrm{M}}$	→	kwa$^{\mathrm{LH}}$ kjahʔʂ^{H}	give his

d. Vacuous Sandhi Output: **H → H / LH.___**

e. Sandhi Blocked: **LM → LM / LH.___**

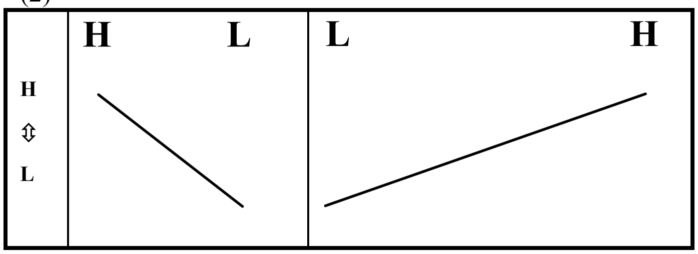
f. Allophonic Sandhi Output: **LH → *MH* / LH.___**

kwa$^{\mathrm{LH}}$ ŋi$^{\mathrm{LH}}$	→	kwa$^{\mathrm{LH}}$ ŋi^{MH}	give salt
kwa$^{\mathrm{LH}}$ loh$^{\mathrm{LH}}$	→	kwa$^{\mathrm{LH}}$ loh^{MH}	give a cactus
kwa$^{\mathrm{LH}}$ kũh$^{\mathrm{LH}}$	→	kwa$^{\mathrm{LH}}$ kũh^{MH}	give a stone

First, observe that the sandhi trigger consists of a **LH** tonal pattern. So, for example, in (1a) a lexical **L** tone becomes **HL** when preceded by **LH**. In (1b), a lexical **M** tone becomes **HM** in this context. Both of these outputs, **HL** and **HM**, are allophonic, as neither is present in the lexical tonal inventory. In (1c), notice that a lexical **M** tone on a vowel that is followed by aspiration neutralizes to **H**. This in fact is the only sandhi output that is neutralizing. In (1d), sandhi may be analyzed as applying vacuously in the context of a lexical **H** tone target. (1e) shows that lexical **LM** is the only tone pattern which cannot be analyzed as undergoing sandhi. In this context, then, sandhi is blocked. The final lexical tone pattern is **LH**. Here, sandhi raises **L** to **M**, and the output is **MH**.

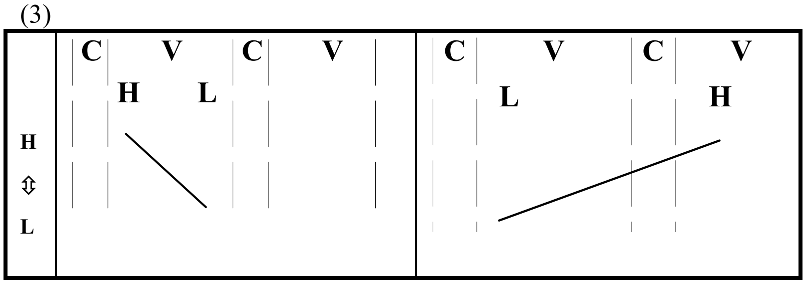
The tonal patterning in Comaltepec is consistent with at least two observations of Hyman and Schuh (1974), in their discussion of universals of tone systems. First, tone spreading is far more often rightward than leftward, and second, spreading is far more likely to take place when the pitch interval between the two tones is relatively great. How might we account for the observations of Hyman and Schuh, which are both common in general, and present in Comaltepec in particular? It is here that I turn to the physical systems that may be affecting tonal processes. First, as shown by Sundberg (1973), as well as Ohala and Ewan (1973), pitch rises are accomplished much more slowly than pitch falls. This is shown schematically in (2).

(2)



Now, if we superimose a supralaryngeal configuration on the laryngeal acoustic pattern here, the motivation for apparent tone spreading becomes clear. This is shown in (3).

(3)



Given that a consonant may be implemented just as the higher pitch is finally being achieved, and given that the consonant, at least if an obstruent, reduces both airflow and energy, the higher pitch may not be saliently encoded in the speech signal if it is realized only on its syllable of origin. Instead, if it is realized both just before, as well as after this second consonant, that is, on the following vowel, it may be encoded saliently. Consequently, **H** tones in **LH** contours are much more likely to "spill over" on to a following vowel (Ohala 1978).

For the remainder of this paper, I employ a variant of Browman and Goldstein's Articulatory Phonology notation (1986, 1989, 1990a, 1990b, 1992), which, as will become clear in a moment, effectively portrays the sandhi process we're looking at. Gestures that are saliently encoded in the speech signal are indicated in black. Not-so-saliently encoded gestures are indicated in dark gray, and unencoded gestures are indicated in light gray.

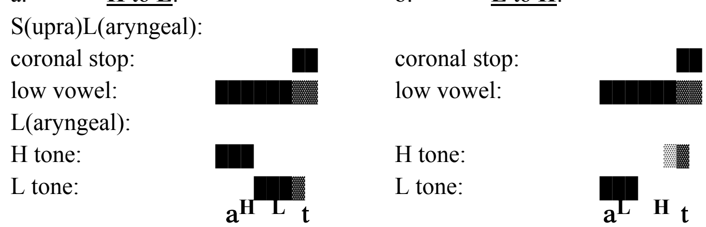
(4) █ = optimally recoverable
▒ = sub-optimally recoverable
▓ = unrecoverable

Now look at (5), in which the tonal contour patterns are restated in gestural notation.

(5) a. **H to L**: b. **L to H**:

HL sequences may be realized in a far shorter temporal domain, and **LH** sequences take longer to implement. And again, in (6a), a **HL** sequence can be implemented without trouble even when a consonant follows, but in (6b), a following consonant may prohibit the robust achievement of the **H** component of a **LH** contour.

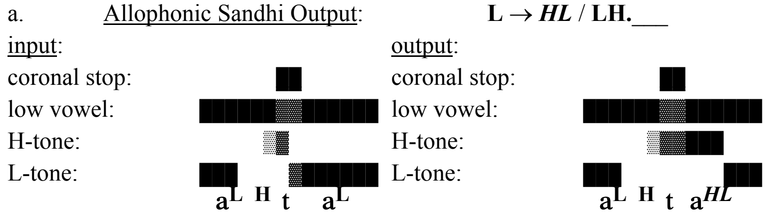
(6) a. **H to L**: b. **L to H**:



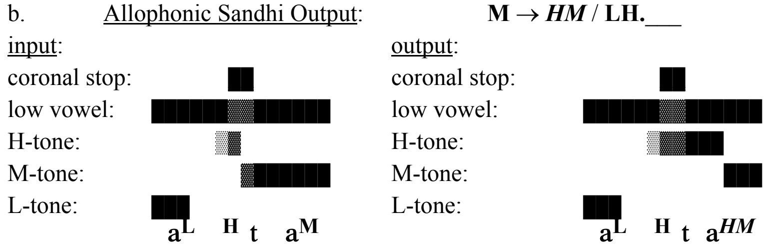
With these physical constraints in mind, let's once again consider the various patterns in Comaltepec.

(7) sandhi patterns:

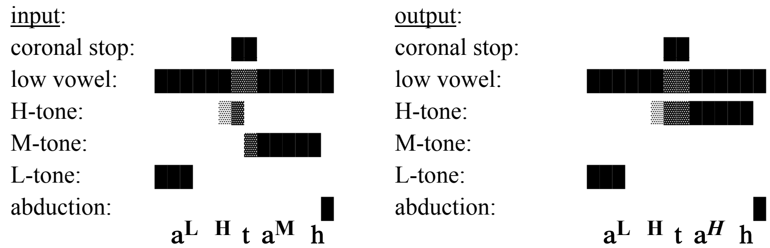
a. Allophonic Sandhi Output: **L → *HL* / LH.___**



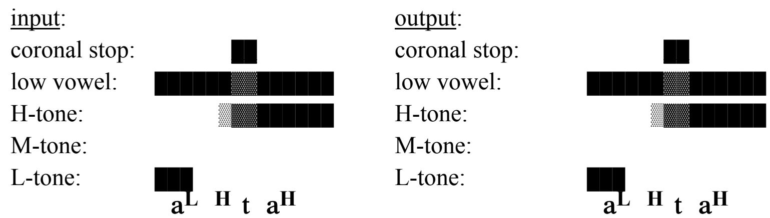
b. Allophonic Sandhi Output: **M → *HM* / LH.___**



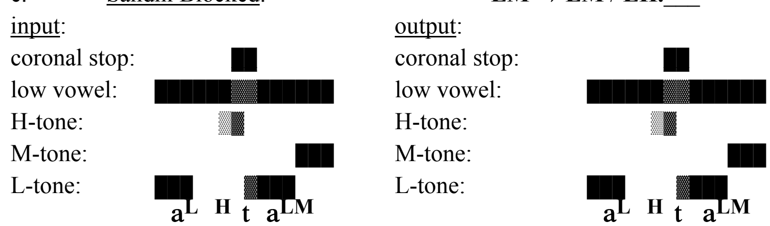
c. Neutralized Sandhi Output: **Mh → *H*h / LH.___**



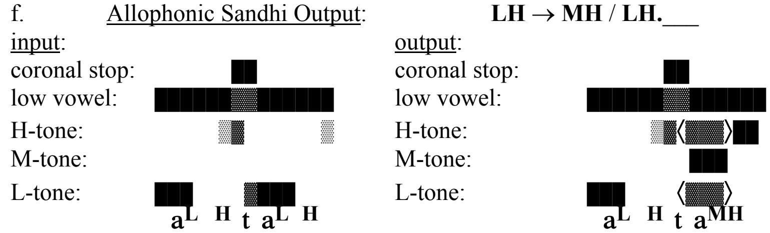
d. Vacuous Sandhi Output: **H → H / LH.___**



e. Sandhi Blocked: **LM → LM / LH.___**



f. Allophonic Sandhi Output: **LH → MH / LH.___**

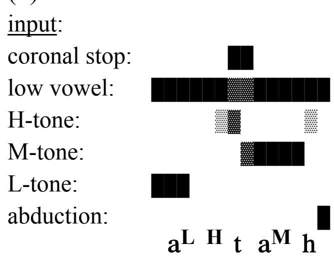


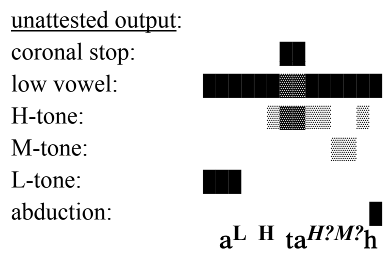
(where ⟨▓▓⟩ indicates the pre-blended value)

In (7a). **L** becomes **HL** after **LH**. Since the **H** component of the **LH** contour is jeopardized, it is realized on either side of a following consonant. And so in the context of a following **L** tone, this rightward vowel surfaces with a **HL** contour. (7b) shows a **M** tone target, and again, this pattern is realized with an additional **H** on its left edge, which saliently encodes the preceding **H** component of the **LH** contour. In contrast, (7c) shows that **M** tones in which aspiration follows are realized as **H** tones, thus neutralizing with lexical **H**s. I motivate this neutralization below. In (7d), sandhi may be analyzed as applying vacuously, as the following tone is **H** anyway. In (7e), when the potential sandhi target is **LM**, sandhi is blocked. Observe that this results in a less-than-robust realization of the preceding **H**: it is only realized at the end of it's syllable of origin. Again, I motivate this peculiar blocking behavior below. Finally, in (7f), in the context of **LH**, sandhi is again allophonic, here resulting in a **MH** contour. Observe that the gestural notation offers a straightforward motivation for this pattern. Here, the spread **H** tone comes to overlap with **L**. In the gestural model, the overlap of conflicting gestures is remedied by what is termed "gestural blending" in which the two values merge toward an intermediate value. And so overlapping **H** and **L** merge to **M**.

Now that we have a handle on the physical systems that may be influencing the sandhi process, let's move on to consider abstract functional forces. Here, it's important not to overlook the ultimate goal of a phonology, that is, to render elements of meaning distinct from one another without excessive effort. Now recall that sandhi is almost always allophonic, and almost never neutralizing. In fact, it turns out that sandhi is neutralizing only when the contrast is inherently weak, that is, when it would take too much articulatory effort to render the contrasts distinct. Let's consider this now. Recall that **M** syllables which neutralize with **H** always possess post-vocalic aspiration. In fact, in contrast to many languages, post-vocalic aspiration is accompanied by a moderate pitch rise in Comaltepec (Silverman 1994, 1995a, 1995b), as shown schematically in (8).

(8)

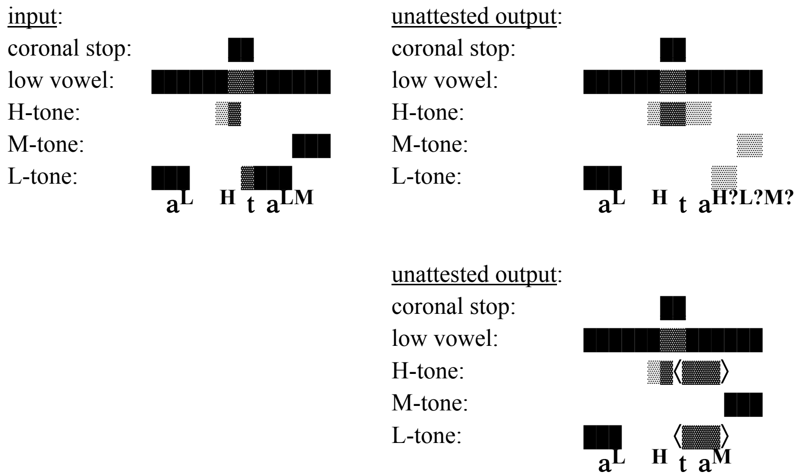




If sandhi were to retain an allophonic character here, the output form would require a quick movement from **H** to **M**, and then, in order to implement post-vocalic aspiration, another pitch increase. I suggest that implementing this many subtle pitch changes within such a short temporal domain is simply not worth the articulatory effort to encode all these tonal contrasts saliently. In fact, even if all pitch contours *are* implemented here, they would suffer from perceptual non-salience, and the listener would conclude that that the tone sequence was actually a level **M** tone. But regardless of its origins, in Comaltepec, tough-to-achieve and tough-to-perceive **M** tones are elided in this context, and the output is articulatorily eased, although, and this is most important, contrast maintenance is forfeited.

So let's move on to consider the other exceptional sandhi pattern, that is, sandhi blockage in the context of a potential **LM** target. There are several conceivable outputs here. Consider (9).

(9)



(where ⟨▓▓⟩ indicates the pre-blended value)

First, **H** may indeed spread, and the lexical **LM** might be crowded onto the remaining portion of the vowel. While this might achieve an okay realization of the **H** tone, **L** and **M** would involve a very short duration each. Again, these tones might get lost in the shuffle, and any functional gain made by salvaging the **H** tone would be overridden by losing the **L** and **M**, either articulatorily or perceptually.

Alternatively, **H** might spread, and merge with the lexical **L**, in another case of blending. But consider the output here, level **M**, which is lexical. So the **H** would survive, but the changed tone would offer no functional gain.

What we find, then, is sandhi blockage. This surface form results in a so-so realization of **H**, with the potential target form fully salvagable. In other words, all contrasts are salvaged without exessive effort, but the salience of lexical **H** is partially reduced. So, since sandhi here would obliterate a perfectly good contrast, it is blocked, and only a so-so contrast survives.

In summary, **L** and **M** have allophonic outputs. **M** targets followed by aspiration is an inherently poor contrast, and so **H** spreads, optimizing its salience at the expense of the target. Sandhi is vacuous with **H** targets, and is blocked with **LM** targets, as this would neutralize a robust contrast. Finally, sandhi produces an allophonic output in **LH** forms.

How might we formally characterize the Comaltepec sandhi patterns? I choose to take seriously the claim that the phonology may be viewed as a struggle between ease of perception and ease of production (Martinet 1952, Lindblom 1990). Since there is no principled reason why a constraint-based grammar cannot be stated in functionally motivated, extra-linguistic terms, Optimality Theory (Prince and Smolensly 1993, McCarthy and Prince 1993) allows us to formally express this struggle.

The primary goal of a phonology, of course, is to render forms distinct. Thus a primary constraint family values rendering contrasts recoverable. Let's call this family **recover**. A contrastive state that is optimally recoverable is in full accordance with **recover**, while a contrast that is sub-optimally recoverable is not. So no stars here indicates that the given cue is fully recoverable. A single star indicates sub-optimal recoverability, and two stars indicates an unrecoverable cue.

(10) **recover:**

	(no stars)	= cue fully (optimally) recoverable
*	1 star	= cue sub-optimally recoverable
**	2 stars	= cue not present; unrecoverable

In contrast, encoding contrasts should not require excessive effort. Economization of effort is thus valued as well. Consequently, any implemented gesture violates what I term **economize**. Here, every implemented gesture receives a star, since every implemented gesture involves an expenditure of effort.

(11) **economize:**

	(no stars)	= gesture not implemented
*	1 star	= gesture implemented

Let's first consider **L** targets, which involve the achievement of lower pitch through laxing the vocal folds. Here if we rank the recovery of all contrasts above economization of effort, we characterize the attested allophonic output.

(12) Allophonic Sandhi Output:

	input: $\mathbf{a^{LH}ta^{L}}$	**recover**	**economize**
a ☞	$\mathbf{a^{LH}ta^{HL}}$	lower pitch higher pitch lower pitch	*slack vocal folds *stiff vocal folds *slack vocal folds
b	$\mathbf{a^{LH}ta^{L}}$	lower pitch ***!higher pitch** lower pitch	*slack vocal folds *stiff vocal folds *slack vocal folds
c	$\mathbf{a^{L}ta^{L}}$	lower pitch ***!*higher pitch** lower pitch	*slack vocal folds stiff vocal folds slack vocal folds

H is saliently encoded upon spreading, and no other contrast suffers. In fact, allophonic processes might often be characterized in these functional terms, that is, "expend the necessary effort to maintain contrasts in an environment that would otherwise jeopardize contrasts." Here, spreading the **H** renders all cues salient. In contrast, non-spreading here, in the second row, would jeopardize the realization of the contrastive higher pitch, and so this candidate loses. Finally, in the last row, deleting the gesture responsible for achieving higher pitch would neutralize the contrasts, and its recovery would be forfeited.

A similar explanation accounts for sandhi in **M** tone domains.

(13) Allophonic Sandhi Output:

	input: $a^{LH}ta^{M}$	**recover**	**economize**
a ☞	**$a^{LH}ta^{HM}$**	lower pitch higher pitch middle pitch	*slack vocal folds *stiff vocal folds *semi-slack vocal folds
b	**$a^{LH}ta^{M}$**	lower pitch ***!higher pitch** middle pitch	*slack vocal folds *stiff vocal folds *slack vocal folds
c	**$a^{L}ta^{M}$**	lower pitch ***!*higher pitch** middle pitch	*slack vocal folds stiff vocal folds *semi-slack vocal folds

Again, spreading **H** renders all contrasts recoverable with no appreciable loss to other cues, whereas not spreading jeopardizes the **H**, and deletion neutralizes the **H**.

But now consider the neutralized form, characterized in the table in (14).

(14) Neutralizing Sandhi Output:

	input: $a^{LH}tah^{M}$	**economize: neutralize M** **Mh → *H*h / LH.___**	**recover**	**economize**
a ☞	$a^{LH}tah^{H}$		lower pitch higher pitch **middle pitch	*slack vocal folds *stiff vocal folds semi-slack vocal folds
b	$a^{LH}tah^{HM}$	***!semi-slack vocal folds**	lower pitch higher pitch *middle pitch	*slack vocal folds *stiff vocal folds
c	$a^{LH}tah^{M}$	***!semi-slack vocal folds**	lower pitch *higher pitch middle pitch	*slack vocal folds *stiff vocal folds
d	$a^{L}tah^{M}$	***!semi-slack vocal folds**	lower pitch **higher pitch middle pitch	*slack vocal folds *stiff vocal folds

Here, as I've discussed, either it is not worth the articulatory effort to salvage the target **M** tone, or the **M** tone is insufficiently salient to be encoded. Consequently, while all other contrasts are retained, this particular contrast is lost. For the present, I characterize this pattern by isolating that contrast which is forfeited in the relevant environment, and ranking the economization of effort higher than recovery, but for this cue only, and in this environment only. This particular constraint, of course should ultimately be superceded by a family which characterizes neutralization in general. So a cue that is not worth the effort to implement, or is insufficiently salient even if implemented, is lost in the relevant environment. So what do we end up with? The semi-slack vocal folds necesary to achieve the **M** tone are forfeited. This is characterized by ranking economization of effort higher than recovery, but for this gesture only, and in this environment only. So any candidate in which the necessary gesture is implemented violates this highest ranking constraint. Beyond this, however, all contrasts are valued, and so all other cues are implemented. And I should also point out that this constraint may just as readily be present in all tables presented, but is only active in (14), where the relevant environment is present. So in (14a), **M** deletes, and thus the attested form is correctly characterized. In (14b-d) **M** is retained, thus violating the neutralization constraint.

I should point out that I do not view this neutralization constraint, **Mh → *H*h / LH.___**, as some sort of linguistic universal that happens to be highly ranked in Comaltepec, and lower ranked in systems in which it is not active. Rather, what is universal here is the tendency to neutralize those contrasts which are jeopardized in some particular environment. What such an environment is, of course is influenced by (universal) phonetic factors, as well as abstract (universal) principles of contrast maintenance and conservation of effort.

In (15), H targets involve vacuous sandhi, and require little commentary.

(15) Vacuous Sandhi Output:

	input: $\mathbf{a^{LH}ta^{H}}$	**recover**	**economize**
a ☞	$\mathbf{a^{LH}ta^{H}}$	lower pitch higher pitch	*slack vocal folds *stiff vocal folds

But consider sandhi blockage in (16).

(16) Sandhi Blocked:

	input: $\mathbf{a^{LH}ta^{LM}}$	**recover**	**economize**
a ☞	$\mathbf{a^{LH}ta^{LM}}$	lower pitch *higher pitch lower pitch middle pitch	*slack vocal folds *stiff vocal folds *slack vocal folds *semi-slack vocal folds
b	$\mathbf{a^{LH}ta^{HLM}}$	lower pitch *higher pitch ***!lower pitch** *middle pitch	*slack vocal folds *stiff vocal folds *slack vocal folds *semi-slack vocal folds
c	$\mathbf{a^{LH}ta^{M}}$	lower pitch *higher pitch ***!*lower pitch** middle pitch	*slack vocal folds *stiff vocal folds slack vocal folds *semi-slack vocal folds
d	$\mathbf{a^{L}ta^{LM}}$	lower pitch ****!higher pitch** lower pitch middle pitch	*slack vocal folds stiff vocal folds slack vocal folds *semi-slack vocal folds

Here, interestingly enough, the recovery of all cues is most highly valued, and although the would-be **H** tone trigger is not fully salient, it is optimal, given the environment in which it is stuck. Spreading **H** would jeopardize the entirety of the sandhi target, either through tone crowding (in the second row) or through neutralization (in the third row). **H** deletion, in the last row, of course, is most undesirable from a recovery point of view. So even here, **recover** outranks **economize** for every cue, and all contrasts are salvaged, if not maximally salient.

Finally, in (17), **LH** targets become allophonic **MH**.

(17) Allophonic Sandhi Output:

	input: $\mathbf{a^{LH}ta^{LH}}$	**recover**	**economize**
a☞	$\mathbf{a^{LH}ta^{MH}}$	lower pitch higher pitch middle (<hi/lo) pitch *higher pitch	*slack vocal folds *stiff vocal folds *semi-slack vocal folds *stiff vocal folds
b	$\mathbf{a^{LH}ta^{LH}}$	lower pitch ***!higher pitch** lower pitch *higher pitch	*slack vocal folds *stiff vocal folds *slack vocal folds *stiff vocal folds
c	$\mathbf{a^{LH}ta^{HLH}}$	lower pitch ***!higher pitch** **lower pitch *higher pitch	*slack vocal folds *stiff vocal folds *slack vocal folds *stiff vocal folds
d	$\mathbf{a^{L}ta^{LH}}$	lower pitch ***!*higher pitch** lower pitch *higher pitch	*slack vocal folds stiff vocal folds slack vocal folds *stiff vocal folds

Here tone spread and tone merger salvage all contrasts, whereas non-spreading would jeopardize the **H**, shown in the second row, and spreading without merger would jeopardize the target tones through crowding, shown in the third row. Finally, again, deletion does nothing for us.

So to conclude, both phonetic and abstract functional constraints, in necessary combination, may explain tone sandhi in Comaltepec, and probably elsewhere as well, including, for example, Zulu (Silverman 1996). When a contrastive value is in a position that would jeopardize its recoverability, an allophonic process such as tone sandhi may ensure its salience: in Comaltepec Chinantec, the **H** component of **LH** contours spreads rightward in order to be saliently encoded in the speech signal. Allophony may be blocked when a robust contrast would be neutralized: in Comaltepec Chinantec potential **LM** targets block the process, as sandhi here would neutralize this robust contrast. Alternatively, allophony may neutralize a weak contrast: in Comaltepec Chinantec, **Mh** undergo sandhi, as maintaining this contrast with **Hh** is both articulatorily and perceptually difficult. I note finally that it would be quite a challenge to invoke a standard feature-geometric account of tone sandhi here. The challenge here is not so much in getting the representations right, but is instead motivating the process itself. Specifically, what principle of feature geometry would trigger sandhi, and what principle would motivate its blocking behavior in the context of **LM** targets? I close with this question.

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