

# Less Stress, Less Pressure, Less Voice\*

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## 1 Introduction

In this paper, I provide an analysis of Tohono O'odham vowel devoicing with respect to physiological explanation. There are three points in this paper. First, this paper provides data of devoicing (consonants and vowels) in Tohono O'odham. Second, analysis of devoicing in terms of subglottal pressure drop is provided. Third, the devoicing is accounted for within the framework of OT (McCarthy and Prince 1993, Prince and Smolensky 1993).

The organization of the paper is as follows. In section 2, the background of the language including both voiced and voiceless vowels is described. In section 3, the data of Tohono O'odham words with voiceless vowels are provided. Then the distribution of devoiced segments is discussed. In section 4, an analysis of devoicing with respect to subglottal pressure drop is presented with schematic diagrams. Then an OT account utilizing phonetic constraints is presented.

## 2 Background

Tohono O'odham is a Uto-Aztecan language spoken in southern Arizona and northern Mexico. In this language, both consonant and vowel devoicing phenomena are found. This fact is interesting because some languages have either consonant devoicing (Dutch: Booij and Rubach 1987) or vowel devoicing (Japanese: Shibatani 1990), but it is rare to find a language which devoices both consonants and vowels.

### 2.1 Voiceless vowels

Native speakers of Tohono O'odham distinguish [go:kj] 'a species of cactus', a word with a voiceless vowel, from [go:k] 'two', a word without a voiceless vowel. Since the voicing of [j] is reduced and the coda consonant [k] is

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pronounced with a release, the two words sound identical to non-native speakers of O'odham.

The orthography, the Alvarez-Hale writing system, distinguishes voiceless vowels from regular vowels. (e.g. regular [i] as *i* vs. voiceless [i̥] as *ĩ*)

## 2.2 Vowels in Tohono O'odham

There are five basic vowels in the language. As shown in (1), the O'odham vowel inventory exhibits an asymmetry. While there are three High vowels (front, central and back), there is only one Mid vowel and only one Low vowel.

### (1) Asymmetric vowel inventory

	front	Central	Back
High	i̥	i̥	u̥
Mid			o̥
Low		ḁ	

The language has only one front vowel [i̥], which is high, and only this vowel appears as a voiceless vowel in Mathiot's (1973) dictionary.

There are very few examples of non-front voiceless vowels (Zepeda 1983)

- (2) heḥḥ            'laugh'  
 wo:po'q        'running (pl)'  
 dahḥ            'sitting'

The environments in which non-front voiceless vowels appear differ from those in which the front voiceless vowel appears. Non-front voiceless vowels appear word-finally preceded by glottal consonants (Hale 1965, Zepeda 1983). Besides the examples above, the vowel [u̥] is devoiced between [k] and [s] ([wakʷs̥] 'flat surface', Hill and Zepeda (1992)). On the other hand, [i̥] is devoiced in an unstressed position preceded by a non-coronal consonant. The devoiced vowels after glottal consonants are optional (Hale 1965), and the devoiced [u̥] between [k] and [s] occurs only in very limited data. Therefore, the analysis here treats only the appearance of the devoiced front vowel.

## 3 Data Description and Analysis

In this section, the data that are used in my analysis are described. The

environment of devoiced [i] (a) is always in an unstressed syllable position<sup>1</sup>, and (b) is preceded by a [-COR] consonant: [Labial] or [Dorsal]. (Fitzgerald and Fountain 1997)<sup>2</sup>.

As mentioned in the introduction, both vowels and consonants can be devoiced in Tohono O'odham. First, vowels are devoiced in word-final position (3).

- (3) final vowel devoicing
- a. [gó:k̥i] 'footprint'
  - b. [jú:k̥i] 'rain'

Word-final consonants are also devoiced, as shown in (4).

- (4) final consonant devoicing
- c. [gá:g̥] 'to look for'
  - d. [kú:b̥] 'to be blowing around'

Third, when a devoiced final vowel is preceded by a consonant, the consonant is also devoiced, as shown in (5).

- (5) final vowel and preceding consonant devoicing
- e. [gá:g̥i] 'looking for'
  - f. [ó:b̥i] 'non-Tohono O'odham person'

Fourth, when the final consonant is sonorant, it is not devoiced (6).

- (6) final sonorant (not devoiced)
- g. [čím] 'small'
  - h. [gíw] 'snow'

However, when these sonorants precede a devoiced vowel, they are also devoiced as in (7). This is interesting because sonorants do not have voiceless counterparts in the phoneme inventory of the language.

- (7) devoicing of sonorants preceding final devoiced vowel
- i. [čí:m̥i] 'a species of a cactus'
  - j. [čí:w̥i] 'jackrabbit'

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<sup>1</sup> The first syllable of a word is never devoiced. The Tohono O'odham primary stress is always on the first syllable (Saxton 1983, Fitzgerald 1996).

<sup>2</sup> They claim that adjacency of [+COR] and [+high] is dispreferred in truncated forms.

In the following sections, the devoicing of phenomena presented in (3) through (7) above are analyzed.

### 3.1 Location of devoiced segment

If the devoicing phenomena are dealt with using alignment constraints, then there must be a systematic position of devoicing in the prosodic structure. For example, a final devoicing would be accounted for by ALIGN [- voice], PROWD, R (8). However, in Tohono O'odham devoicing does not occur in a single prosodic position. I explain why one devoicing environment cannot be determined in the following paragraphs.

- (8) ALIGN [- voice], PROWD, R: Voiceless segment is aligned with the right of prosodic word.

First, as a possibility, the position of devoicing might be the right of a morpheme or root. As shown in (9a) and (9b), however, devoicing is not always in a root. While (9a) shows that devoicing occurs in the end of a root of a word, (9b) shows that devoicing does not need to occur at the end of the root of a word. Also, it does not have to do with the position of a morpheme in a word, as shown in (9c) and (9d). (9c) shows that devoicing can occur at the end of the leftmost morpheme, and (9d) shows that devoicing does not have to occur at the end of the leftmost morpheme in a word.

- (9) Root/Morpheme ? (indicated by [ ])

a.	[jú:kj] 'rain'	[júk̥j][to] 'stop raining'
b.	[ida] 'inside'	[ida][p̥i] 'to remove guts from an animal'
c.	[gi?i] 'fat'	[gi?i][p̥i] 'to remove fat'
d.	[nowj] 'arm'	[nowj][kam] 'one with a hand'

Second, the devoicing does not always correspond to a foot boundary. In order to explain this, I must mention one problem regarding syllables which are elements in foot structure. It is not clear whether Tohono O'odham voiceless vowels are syllabic. I list both cases here in (10). (10a) and (10b) are two cases of voiceless vowels which are footed as syllables. In (10a), devoicing occurs at the right edge of the foot, while in (10b), it does not occur in the same position. Even if voiceless vowels were considered to be non-syllabic, it is impossible to determine the position of devoicing by prosodic position, as shown in (10c) and (10d).

(10) Footing alternations

if voiceless vowels are syllabic

- a. (juk̥i)to
- b. (giʔi)p̥j

if voiceless vowels are not syllabic

- c. (juk̥ito)
- d. (giʔip̥j)

Therefore, the syllabification of a word containing a voiceless vowel is uncertain, and it is a problem for an analysis using an Alignment constraint. Even when we consider both cases, neither case will help determining the environment for the devoicing phenomena. An alternative solution is presented in the following section.

### 3.3 Voicing due to subglottal pressure drop

I make some assumptions here in order to solve this problem. There must be a cause that the devoicing occurs. Also, there must be a point where devoicing is targeted. The targets are (i) syllable-final (or coda) position in consonant devoicing, and (ii) unstressed [i] in vowel devoicing (cf. [i] [u] in Japanese Shibatani 1990).

I assume that the cause of devoicing is due to a pressure difference between the subglottal area and the supralaryngeal area. In (11), three axioms are established that will be referred to in the following analysis.

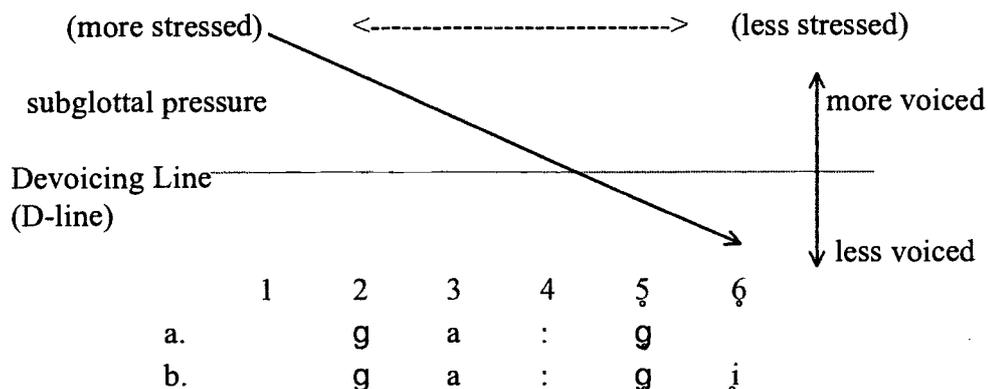
(11) Axioms

- i) Voicing is easier when pressure below the glottis exceeds pressure above the glottis (Bernoulli's principle).
- ii) Supralaryngeal pressure is higher for obstruents than for sonorants.
- iii) Subglottal pressure falls following a stressed syllable (Lehiste 1970).

I make two specific assumptions for the O'odham devoicing. One is that the vowel [i] is targeted for devoicing in Tohono O'odham when in unstressed position. Another is that consonants in coda position are targeted for devoicing.

The schematic diagrams shown in (12) illustrate the relationship between devoicing and subglottal pressure drop.

(12) Schematic illustration of devoicing and pressure interaction.

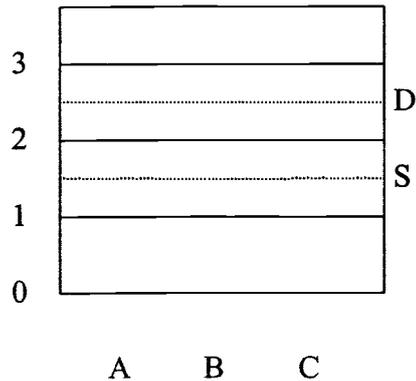


The diagonal line indicates the subglottal pressure drop. The higher the line, the greater the pressure. The dotted line shows the gradation of stress. Towards the left is more stressed, and towards the right is less stressed. The vertical line shows the gradation of voicing. The higher the line, the more voiced, and the lower the line, the less stressed. The horizontal line lies in the middle is called the Devoicing Line or D-line. When the subglottal pressure is above this line, the segment is pronounced as voiced. On the other hand, when the pressure is below the line, the segment is pronounced as unvoiced. Although the features utilized, stress, pressure and voicing, are all gradient, this D-line categorizes segments into two categories: stressed or unstressed, voiced or unvoiced.

This will treat the devoicing of both final consonants and final hi-front vowels well. However, there is a problem with this diagram. In O'odham, final sonorant consonants are not devoiced. The diagram above does not distinguish between obstruents and sonorants (Axiom ii).

In order to solve this problem, I add another assumption to the ones already presented above. That is, there is another line below D-line where sonorants are recognized as voiceless. I call this the Sonorant Devoicing Line (S-line). The modified diagram is shown in (13).

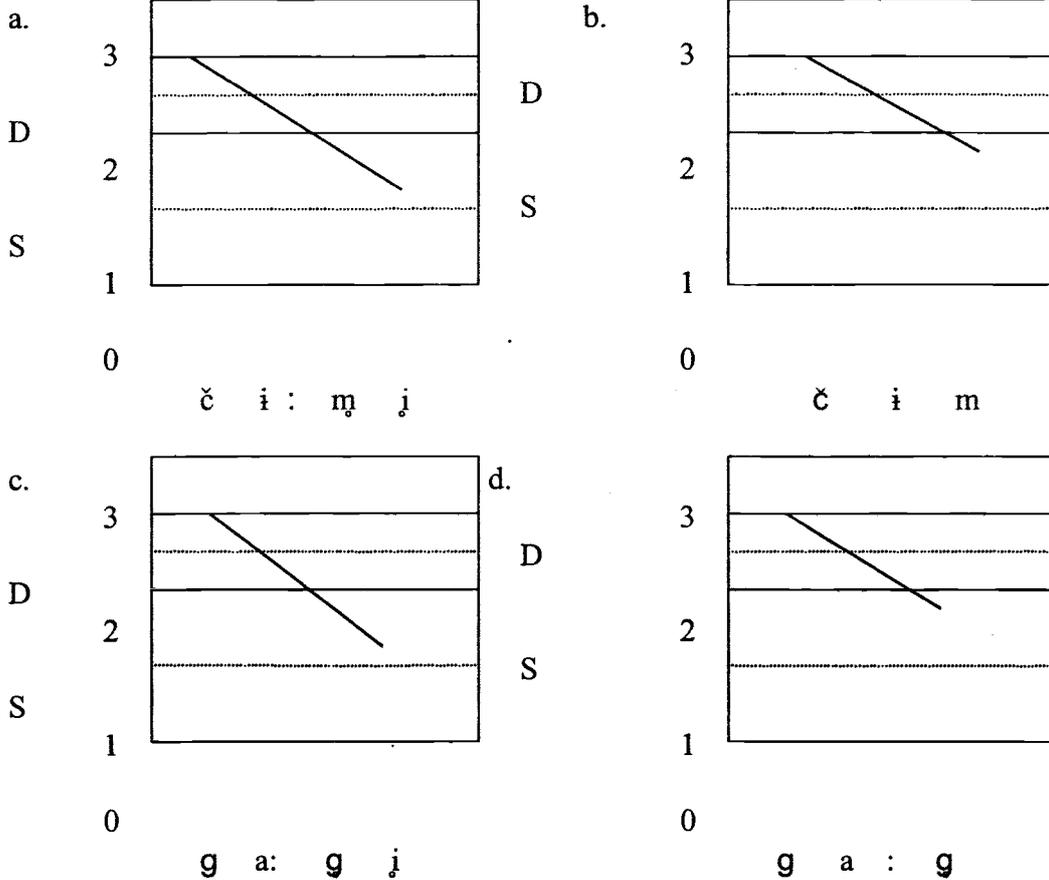
(13) Modified schematic illustration



The vertical axis is numbered from 0 to 3 to show the strength of subglottal pressure. The D-line is located between 2 and 3, and the S-line is located between 1 and 2. A devoiced vowel's subglottal pressure falls down to 0, and a devoiced consonant's subglottal pressure falls down to 2. Note that obstruents are devoiced when the subglottal pressure is below the D-line, and sonorants are devoiced when the subglottal pressure is below the S-line.

The graphs below (14) show the subglottal pressure drop and devoicing of the four words, [č̥i:m̥j][č̥im][g̥a:g̥j] and [g̥a:g̥]. Slope of the line for the subglottal pressure drop varies depending on the targeted segment (steeper for a word with a devoiced vowel than for a word with a devoiced consonant), and the length of the word (the shorter the word is the steeper the slope is).

(14)



Having two separate points for obstruent and sonorant devoicing accounts for the sonorant not being devoiced when it is at the end of a word, but devoiced when it is followed by a devoiced vowel. In the following section, I present an analysis in terms of OT. The assumptions and analysis given above are all reflected.

#### 4 OT Account

In this section, an OT analysis is provided. My OT analysis departs from the standard OT in that candidates show gradient subglottal pressure. No such phonetic information is represented in standard OT. Different pressure levels are represented by three different font sizes (see 15) in the tableaux. Segments pronounced with the subglottal pressure above D-line are represented in the largest font size. Those pronounced with subglottal pressure between D-line and S-line is indicated by the middle font size. The smallest font size indicates the segments pronounced with subglottal pressure below S-line.

- (15) X: above D-line  
 X: below D-line, above S-line  
 x: below S-line

The first constraint introduced here is [-V]<DLINE (16).

(16) [-V]<DLINE: Obstruents are devoiced when the subglottal pressure is below D-line (combination of axioms 1 and 2)

This constraint eliminates candidates with no final consonantal devoicing. In tableau (17), both candidates have final consonant that are below D-line. Candidate (a) is selected because the final consonant is devoiced, while candidate (b) fails because its final consonant is not devoiced.

(17) input: ga:g ‘to look for’

		[-V]<DLINE
☞ a	gá:g	
b	gá:g	*!

With this constraint, there is a problem for final sonorant consonant. Since sonorants behave differently from obstruents, candidates with sonorant final consonants are incorrectly evaluated as shown in (18). In the tableau below, candidate (b) is incorrectly selected for devoicing the last consonant. However, this last consonant is sonorant, and sonorants in O’odham should not be devoiced in final position. The correct candidate must be candidate (a). This suggests that the constraint [-V]<DLINE alone cannot account for the O’odham devoicing phenomena. Another constraint is introduced next.

(18) input: čím ‘small’

		[-V]<DLINE
☞ a	čím	
⊗ b	čím̥	

The next constraint is SONORANTVOICING (SV).

- (19) SV: Sonorants are voiced. (combination of Axioms 1 and 2)

This captures the analysis in the previous section that a sonorant consonant is still voiced even when its subglottal pressure is below the D-line only if it is above the S-line. The tableau below shows the evaluation with both constraints. Now, the correct candidate (a) is selected, because it satisfies SV. Candidate (b) is ruled out because the last consonant which is sonorant is devoiced.

(20) input: čím ‘small’

	SV	[-V]<DLINE
☞ a	čím	
b	čím̥	*!

So far, both devoicing of the final obstruent consonants and non-devoicing of the final sonorant consonants are accounted for.

There is another devoicing phenomenon that needs to be accounted for. When a consonant is followed by a devoiced vowel, the consonant must be devoiced, regardless of its sonority. With these two constraints given above there is a problem for a devoiced vowel preceded by a sonorant consonant. The problematic evaluation is shown in tableau (21) below. Candidate (a) is the correct output, but it is ruled out because it violates SV in that the last two segments are devoiced although they are sonorants. Candidate (b) violates SV once. As a result, candidate (c) is selected because its last two sonorant segments do not violate SV.

(21) input: čí:mi ‘a species of cactus’

	SV	[-V]<DLINE
☞ a	čí:m̥i	*!*
b	čí:m̥i	*!
Ⓢ c	čí:mi	

Another constraint is introduced below in order to solve this problem. The constraint is [-V]<SLINE, and it states that sonorant segments are devoiced when the subglottal pressure is below S-line.

(22) [-V]<SLINE: Sonorants are devoiced when the subglottal pressure is below the S-line (combination of Axioms 1 and 2).

The tableau below shows the correct evaluation of 'čǐ:mi'. Candidate (a), which is the correct output, is now optimal because it satisfies the [-V]<SLINE constraint which dominates SV. Candidates (b) and (c) fail since they violate the [-V]<SLINE constraint.

(23) input: čǐ:mi 'a species of cactus'

	[-V]<SLINE	SV	[-V]<DLINE
a		**	
b	*!	*	
c	*!*		

With these constraints and this ranking, the sequence of obstruent and devoiced vowel is also accounted for. In (24), candidates (a) and (b) satisfy the constraint [-V]<SLINE by devoicing [i] due to the subglottal pressure being lower than S-line. Since candidate (c) violates it, this is ruled out. Candidate (a) is then chosen because it violates only one of the lower constraints, while candidate (b) violates both constraints.

(24) input: ga:gi

	[-V]<SLINE	SV	[-V]<DLINE
a		*	
b		*	*!
c	*!		*

In sum, the constraints and their ranking are as shown in (25). [-V]<SLINE outranks SV and [-V]<DLINE, and ranking between SV and [-V]<DLINE is insignificant.

(25) Ranking: [-V]<SLINE >> SV, [-V]<DLINE

Although the analysis given above accounts only for Tohono O'odham devoicing phenomena, it is predicted that a language with a SV >> [-V]<DLINE >> [-V]<SLINE constraint hierarchy will have final obstruent devoicing but no vowel devoicing. This type of language is seen relatively commonly (e.g. German, Dutch, and Russian). It may not, however, predict the existence of languages that have only vowel devoicing, such as Japanese. Such languages devoice vowels

only in environments where they are preceded or surrounded by non-voiced segments. Therefore, the schema given above still accounts for such languages.

## 5 Conclusion

In this paper, devoicing in Tohono O'odham is accounted for by phonetic constraints in a phonological framework (OT). Three constraints, SV, [-V]<SLINE and [-V]<DLINE and their ranking shown in (25) select the correct outputs in Tohono O'odham devoicing. The appearance of voiceless vowels in O'odham is not systematic in terms of alignment. In other words, alignment constraints are irrelevant for an OT analysis in the case of devoicing phenomena. Obstruents and sonorants are recognized as voiceless when they fall below two different subglottal pressure levels: D-line and S-line. Also, devoicing is accounted for in this analysis in terms of subglottal pressure. I did not utilize the stiffness and spreadness of the glottis for this analysis (cf. Halle and Stevens 1971). Changes in these features would alter the basic picture of the devoicing range shown in the diagrams. My analysis shows that the devoicing is accounted for by the use of subglottal pressure drop without these glottal features.

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