Sonority-Driven Stress does not Exist

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1   Introduction

This paper provides new evidence against previous descriptions that stress assignment in Gujarati is sonority-driven (cf. Cardona 1965, Adenwala 1968, Mistry 1997, de Lacy 2002, Cardona & Suthar 2003, Doctor 2004, Schiering & van der Hulst 2010, Modi 2013). I will show that stress in Gujarati is not sensitive to vowel sonority, based on acoustic evidence. Specifically, I will argue that the highly sonorous vowel [a] does not attract stress from the default position – stress always falls on the penult. There are several theoretical, methodological, and pedagogical implications of this finding (see §6 for discussion). Most importantly, it casts doubt on the existence of sonority-driven stress because Gujarati is the most extensively described case (de Lacy 2002, 2006, 2007).

A 'sonority-driven' stress system is one where the relative sonority of syllabic nuclei helps determines the optimal stress-bearing unit; the universal sonority hierarchy is given in (1) (Kenstowicz 1997, de Lacy 2002, 2004, 2007).

(1)   Universal sonority hierarchy (Kenstowicz 1997:162, de Lacy 2002:55)
          low peripheral > mid peripheral > high peripheral > mid central > high central

Peripheral vowels are more sonorous than central ones, and within those groups lower vowels are more sonorous than higher ones.

Of all known sonority-driven stress systems, Gujarati is probably the most well described case with distinctions among peripheral vowels (de Lacy 2004:193). Although the descriptions disagree on many points (see §2.1), almost every description agree that stress seeks out the highly sonorous vowel [a], disregarding the default penultimate position. Examples are given in (2).

(2)   Gujarati stress in brief (data from de Lacy 2002:72)
          a. Default stress on penult
             [sáɖa]   'plus 1/2'
             [dʒája]   'let's go'
          b. Stress falls on ultimate [a] if penult is a non-[a]
             [ʃikáɾ]   'recently'
             [hɛɾán]   'distressed'
          c. Stress falls on penultimate [a] if ultima is a non-[a]
             [sáme]   'in front'
             [sáɖu]   'plain'

In (2a), stress falls on the penult when both vowels are [a]. However, stress is retracted to [a] in the final position when the penult contains vowels other than [a], as in (2b). If the ultima contains a non-[a], stress falls on the penultimate position, as in (2c). In other words, [a] is more sonorous than other vowels, so if a syllable that contains [a] attracts stress away from the default position, one can refer this as sonority-driven stress.

The goal of this work is to determine whether Gujarati's [a] does in fact attract stress. I focus on the acoustic realization of stress. Cross-linguistic studies have shown that multiple acoustic measures may correlate with stress in vowels. Typically, stressed vowels may have a higher pitch (e.g. Lieberman 1960, Gordon 2004, Gordon & Applebaum 2010), greater intensity (e.g. Fry 1955, Liberman 1960, Everett 1998, Gordon 2004, Gordon & Applebaum 2010, Gordon & Nafi 2012), and longer duration (e.g. Fry 1955, Lieberman 1960, Everett 1998, Gordon 2004, Gordon & Applebaum 2010). Differences in F1 and F2, associated with difference in vowel quality, have also been found (e.g. Gordon 2004, Garellek & White 2012). I will report results from vowel quality and intensity to show that [a] does not attract stress. Instead, I will show that stress regularly falls on the penultimate syllable. Due to limited space, this paper provides only a summary of findings for intensity F1, and F2. For more details, see Shih (in prep.). This study is, with Bowers (in prep.), among the few to extensively acoustically analyze a putative case of sonority-driven stress (also see Lehiste *et al.* 2005).

2   Background

2.1   *Disagreement*   At this point, it is important to acknowledge the nature and extent of the disagreement between previous descriptions. Several descriptions also present quite different principles for stress assignment in disyllables vs. trisyllables, too; these will be discussed where relevant.

In some descriptions, the position of stress is fixed. For example, Turner (1921) claims that stress generally falls on the penultimate syllable, regardless of word length. Similarly, Master (1925) reports that stress always falls on the penult in disyllables. Patel & Mody (1960) report that stress always falls on the initial syllable in both disyllables and trisyllables.

For descriptions that report sonority influence, the default position of stress is uniformly reported to fall on the penult in disyllabic words (Cardona 1965, de Lacy 2002, Mistry 1997, Cardona & Suthar 2003, Doctor 2004, Schiering & van der Hulst 2010). There is disagreement about stress position in trisyllabic words. Mistry (1997) reports that stress is on the initial syllable, while de Lacy (2002) claims that the penult has stress, as does Cardona (1965), Cardona & Suthar (2003), Doctor (2004), and Schiering & van der Hulst (2010). The present study focuses entirely on disyllabic words.

Regardless, the central point on which almost all descriptions agree is that Gujarati stress falls on the penultimate/initial syllable in the default situation in disyllables. The only dissent is from Adenwala (1968), who reports that stress falls on the ultimate syllable when a disyllabic word contains [i] and [u].

Most descriptions agree that stress is affected by vowel quality. However, as (3) shows, there are significant variations between descriptions. Most agree, however, that [a] can attract stress away from the penultimate position to either the antepenult or final syllable if the penult is not [a]. In contrast, Adenwala (1968) reports that stress is attracted to all non-high peripheral vowels (not just [a]), and Modi (2013) does not recognize any stress influences among peripheral vowels.

Many descriptions also report avoidance of stressed schwa, though such avoidance can be limited. For example, Cardona (1965) and de Lacy (2002) report avoidance of stressing penultimate schwa only if there is a non-schwa in the antepenult. Some descriptions make further quality distinctions, too (e.g. Cardona 1965 and Doctor 2004 for trisyllables, though de Lacy (2006:234) claims that the relevant vowels are deleted).

There is no consensus about the status of mid vowels [ɛ ɔ e o] and high vowels [i u]. Cardona (1965)'s and Doctor (2004)'s descriptions cannot be adequately modeled in Kenstowicz (1997)'s and de Lacy (2002, 2004, 2006)'s theories because they distinguish [i] from [u], though de Lacy (2006:241-242) suggests that [i] is deleted in the majority of these environments.

Moreover, stress assignement is also reported to be affected by other factors: syllable numbers (disyllables and trisyllables), syllable shapes (open and closed syllables), and free variation. However, as the aim of this study is to test the existence of sonority-driven stress, the focus here is on disyllabic words and open syllables only. For detailed discussion, see Shih (in prep.).

Overall, no description of Gujarati stress agrees with any other in all their details; Cardona (1965) and Doctor (2004) are almost identical but still disagree with each other over whether there is free variation. While some reasons for this disagreement will be discussed here, it is important to emphasize the goals and scope of this study do not require perfectly homogeneous descriptions. The present goal is to determine whether Gujarati has sonority-driven stress, and almost every description agrees that it does for disyllables involving [a]. So, the focus of this study will be on disyllables with [a].

(3)   Descriptions of Gujarati stress

Source	a	ɛ ɔ e o	u	i	ə
Penultimate stress					
Turner (1921) Master (1925): 2σ	■	■	■	■	■
Sonority-driven stress					
Mistry (1997) de Lacy (2002): 2σ Cardona & Suthar (2003): 2σ & 3σ	■				
Cardona (1965): 2σ de Lacy (2002): 3σ Doctor (2004): 2σ Schiering & van der Hulst (2010): 2σ & 3σ	■				■
Cardona (1965): 3σ Doctor (2004): 3σ	■			■	
Adenwala (1968): 2σ	■	■			■
Modi (2013): 2σ	■	■	■	■	

To summarize, there have been many descriptions of Gujarati stress, and almost all disagree with each other. It is difficult to interpret the reason for this diversity. Perhaps stress varies significantly even within dialects, or perhaps the impressionistic methods used to determine stress were inadequate. Regardless, almost all of the descriptions agree that the default position of stress is the penult, that stress is influenced by the sonority of vowels in some way – specifically almost all agree that stress seeks out [a], or avoids [ə], or does both. This sonority-sensitivity is the descriptive claim that will be pursued in the remainder of this work.

2.2   *Phonological and phonetic evidence*   Stress-sensitive allophony is mentioned in several descriptions of Gujarati. The central vowel [ə] is realized as [ʌ] when it is stressed (Patel & Mody 1960, Lambert 1971, Nair 1979). Allophonic alternations between high peripheral and non-peripheral vowels [í ú]~[ɪ ʊ] are also reported to be conditioned by stress (Cardona 1965, de Lacy 2002): the non-peripheral allophones appear in non-final open syllables, except when they are stressed. Therefore, allophony provides extremely important evidence for the location of metrical heads. Unfortunately, allophony is the only stress-sensitive phonological process reported in the previous descriptions, and §4.1 will present evidence that allophony does not in fact support the sonority-driven descriptions of stress, but instead is consistent with sonority-insensitive penultimate stress.

All previous descriptions of the phonetic realization of Gujarati stress are impressionistic. Stressed vowels are reported to have a longer duration (Pandit 1958, Adenwala 1968, de Lacy 2006, Modi 2013), raised F_0 (de Lacy 2002, 2006), and greater intensity (de Lacy 2002) than unstressed vowels. When [a] is stressed, it is reported to not only a longer duration (Lambert 1972) but also a higher intensity (Patel & Mody 1960).

For the present study, the general consistency of the phonetic realization of metrical heads discussed above is taken to suggest that stress in Gujarati is likely to be realized by at least one of increased duration, an F0 excursion, higher intensity, and vowel quality (F1, F2), so it is these acoustic properties that are the primary focus of this paper. The acoustic results reported below indicate that Gujarati has consistently penultimate stress rather than sonority-driven stress.

3 Methodology

3.1 *Goal of the experiment*   The goal of the experiment was to test whether there is sonority-driven stress in Gujarati. In particular, [a] is the focus of the experiment because descriptions of Gujarati sonority-driven stress refer to [a] as attracting stress. Following the descriptions in §2.1, two hypotheses were examined, as in (4).

(4)   Competing hypotheses for Gujarati
           a. Sonority-Driven hypothesis
              Stress falls on the penult by default, but falls on a non-penultimate [a] when the penult contains
              a less sonorous vowel
           b. Penultimate hypothesis
              Stress always falls on the penult regardless of vowel sonority.

The motivation for the Sonority-Driven hypothesis is that almost every description of Gujarati stress asserts that [a] attracts stress (see references in §2.1). The motivation for the Penultimate hypothesis is the observation that all the descriptions identify the penult as the default position for stress (see references in §2.1).

Forms such as $[Ca_1.Ca_2]$, $[Ca_3.C\psi]$, and $[C\psi.Ca_4]$ play an essential role in disambiguating the two hypotheses because the two hypotheses predict different stress patterns. Here each [a] is numbered for ease of comparison. The symbol 'ψ' stands for the set of vowels [o, u, i].

(5)   The two hypotheses predicted stress patterns

Penultimate hypothesis	*Sonority-Driven hypothesis*	*Comment*
'Ca_1.Ca_2	'Ca_1.Ca_2	Identical forms
'Ca_3.$C\psi$	'Ca_3.$C\psi$	Identical forms
'$C\psi$.Ca_4	$C\psi$.'Ca_4	Different forms

To disambiguate the two hypotheses, words of the form $[C\psi.Ca_4]$ are crucial. The Penultimate hypothesis predicts that stress should fall on the penult in such words, and so it predicts that $[a_4]$ and $[a_2]$ in $[Ca_1.Ca_2]$ should be acoustically very similar as they are both final and non-heads. The sole difference is the identity of the penult's vowel – $[a_1]$ for $[a_2]$, and one of [i], [o], or [u] for $[a_4]$. In contrast, the Sonority-Driven hypothesis predicts that $[a_4]$ should be acoustically distinct from $[a_2]$. After all, $[a_4]$ and $[a_2]$ are identical – they appear in the same position (ultima); they differ only in metrical headedness.

Furthermore, if the influence of position (penult vs. ultima) is factored out, other comparisons are predicted to be revealing. The Penultimate hypothesis predicts that $[a_1]$ and $[a_3]$ should be acoustically distinct from $[a_4]$, whereas the Sonority-Driven hypothesis predicts $[a_1]$, $[a_3]$, and $[a_4]$ should be acoustically similar.

In summary, in terms of acoustic similarity the Penultimate hypothesis predicts that $a_1=a_3$, $a_2=a_4$, and $a_1/a_3\neq a_2/a_4$ (where '=' means acoustically similar, putting aside non-stress contextual influences); the Sonority-Driven hypothesis predicts that $a_1=a_3=a_4$ and that $a_1/a_3/a_4\neq a_2$.

3.2 *Experiment design*   A word-list was constructed by consulting with three native speakers of Gujarati. Disyllabic words with the shape $[Ca_1.Ca_2]$, $[Ci_1.Ci_2]$, $[Co_1.Co_2]$, and $[Cu_1.Cu_2]$ were used to establish baselines for the acoustic realization of stressed and unstressed vowels. Other word types had the form $[Ca_3.C\psi]$ and $[C\psi.Ca_4]$ (where ψ ranges over [o, u, i]). [ɛ] and [ɔ] were not used because they have a restricted distribution and low frequency of occurrence (Mistry 1997:660). On the other hand, my subjects reported that Hindi words can end with [e], so the mid vowel [e] was also excluded in order to avoid potential confusion with Hindi words. The pairs allowed direct comparison of vowels in both putatively stressed and unstressed states (see §3.1).

The first consonants were limited to aspirated and unaspirated stops [b[(h)] d[(h)] g[(h)] p[(h)] t[(h)] k[(h)]] to reduce influence on the following vowel's duration (van Santen 1992:527-532) and the second consonant was a

voiceless unaspirated or aspirated stop [p⁽ʰ⁾ t⁽ʰ⁾ k⁽ʰ⁾], to keep influence on the preceding vowel's duration relatively constant (Peterson & Lehiste 1960). This stimulus structure not only facilitated identification of vowel boundaries but also minimized segmental effects on vowels (e.g. vowel lengthening before voiced consonants).

There were ten tokens for words with the [Ca.Ca] shape and five tokens for words with the [Cψ.Cψ] shape. There were five tokens for words with the [Ca.Cψ] and [Cψ.Ca] shape, respectively. In sum, there were 55 stimuli in the experiment. There is no published information on word frequency in vernacular words. However, the informants who helped me compile the list reported that the words were all familiar to them and frequently used in everyday conversation. Loanwords from Hindi and English were excluded entirely.

Each word was placed in two frame sentences to control for phrase-final lengthening. All the words were put in sentence-medial position, as shown in (6). It was found that there were different pauses in the frame sentences: a pause before the target word in (6a) and a pause after the target word in (6b). Pause (or phrase-finality) will affect some aspects of the acoustic realization of the final vowel. In this paper I report results only from the post-pausal sentence due to the space limit.

(6)   Two frame sentences
        a. Post-pausal sentence
            [tame a ʃabdə ne _____ kaho   tʃʰo]
             you this word to   read tense-present
            'You read this word ____.'
        b. Pre-pausal sentence
            [a ʃabdə _____ kʰaɾekʰaɾ mastə   tʃʰe]
            this word   really   interesting is
            'This word ____ is really interesting.'

Colloquial filler sentences were employed to encourage subjects' vernacular speech. Fillers were interspersed among the stimuli with a spacing of seven stimuli. In particular, five fillers commenced each session to take into account the effects of any initial nervousness the subject might have about the task. The order of the stimuli was randomized and counter-balanced in each session. There were three recording sessions in this experiment. Participants read 55 stimuli and 15 fillers in each session. Three repetitions were collected, yielding a total of 330 tokens per speaker.

3.3   *Participant* Four male and one female native Gujarati speakers participated in the experiment. Their ages ranged from 19 to 24 years. All had recently moved to the United States and still communicated in Gujarati on a daily basis. Except for one participant who was from a Gujarati community in Mumbai, the rest of participants were from Gujarat State in India. All the participants spoke the standard dialect of Gujarati, including the varieties spoken in Mumbai and Ahmedabad, the former capital of Gujarat. None of the participants had linguistic training or a history of speech impairments. They were naïve as to the goal of the experiment. The participants received nominal monetary compensation for their participation. This paper will report results from one female subject due to the space limit. For discussion on other participants, see Shih (in prep.).

3.4   *Procedure* The experiment was performed at the Phonology and Field Research Laboratory (Phonolab) at Rutgers University. Participants were recorded while sitting in a sound-attenuated booth and wearing an AKG C420 head-worn microphone with behind-the-neck headband in order to keep the microphone at a constant distance from the mouth. The microphone was connected to an ART MPA Gold pre-amplifier, which output to an M-Audio Delta 1010LT sound card. The recording was done using GoldWave v6. 10 at a 44.1k Hz sampling rate and 16 bit quantizing rate in mono.

Participants were presented with words written in Gujarati script on a computer screen. Participants were presented with some of the target words on screen before the recording sessions began to familiarize them with the Gujarati font since Gujarati script is normally written by hand. The words were presented individually without frame sentences; that is, participants had to generate the two predetermined sentences during the experiment. The recording sessions were conducted individually. Participants read the words

when they were ready, at a normal conversational speed. Breaks were given after each recording session. Some effort was expended in ensuring that the subjects employed their vernacular. Specifically, a Gujarati research assistant engaged the participants in vernacular speech by having conversations with them during the breaks about mundane daily activities. The purpose was to ensure the data were elicited from a single phonological module of each participant. As de Lacy (2014:13-16) points out, it is possible to reach wrong conclusions based on pooled data because it might be a mixture of outputs from several distinct phonological modules (e.g. from formal and informal speech styles, or different dialects). All the participants finished the experiment on one day.

3.5 *Measurements*   Acoustic correlates of stressed/unstressed vowels were measured, including duration, F0, F1, F2, and intensity. Using Praat Textgrids (Boersma & Weenink 2015), three intervals were marked: the extent of the first and second vowels of the target word, and the beginning and end of a fixed part of the frame sentence. The fixed part of the sentence was used to measure and correct for speech rate. The speech rate for each token was determined by dividing each fixed part duration by the average duration of all fixed parts.

The left boundary of each vowel was marked at the beginning of the first non-deformed periodic waveform. The right boundary was identified as the end of the second formant, with the help of the third formant when the end of the second formant continued into closure (Turk *et al*. 2006:7). The segmentation was performed by two groups of three research assistants. The results were compared within each group to minimize human error. For each measurement, once the range between the maximum duration and minimum duration was found to be more than five milliseconds, the author re-examined the Textgrids and made corrections.

3.6 *Statistical methods*   I determined whether each of the acoustic measures was a statistically significant correlate of stress of $[a_1]$, $[a_2]$, $[a_3]$, and $[a_4]$ in Gujarati. The values of each measure were analyzed using linear mixed effects models. These were implemented in R (R Development Core Team 2015) using the *lmer()* function of the *lmerTest* package (Kuznetsova *et al*. 2015). The models contained *vowel* and *condition* (different frame sentences) as fixed effects, and *word* as a random effect. For each model, I report t-values provided in the model output, as well as p-values obtained using the *summary()* function.

4 Results and Discussion

4.1 *F1 and F2*   This section presents results of F1 and F2. Recall that allophonic alternations between high peripheral and non-peripheral vowels [í ú]~[ɪ ʊ] are reported to be conditioned by stress (Cardona 1965, de Lacy 2002).
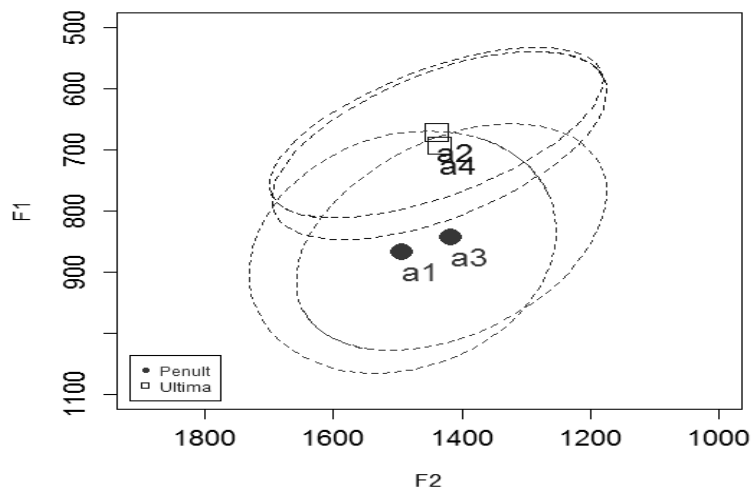

Figure 1: Vowel plot for [a] in different positions. The ellipsis delineates 95% confidence interval.

So, stress might be expected to affect vowel quality: i.e. [a] is expected to have different realization under the condition of stress. If stress is sonority-driven, then the $[a_4]$ in $[C\psi.Ca_4]$ should be stressed and therefore more peripheral than $[a_2]$ in $[Ca_1.Ca_2]$, and potentially the same quality as the stressed $[a_1]$ (as long as no other non-stress factors interfere). If stress falls on the penultimate syllable, $[a_4]$ should be unstressed and thus have a similar vowel quality to $[a_2]$. Therefore, $[a_4]$ plays an important role in disambiguating the two hypotheses.

Results from the linear mixed effect model show that $[a_4]$ and $[a_2]$ belong to the same category while $[a_1]$ and $[a_3]$ form another one, as shown in Fig. 1. Notice that The results are from the data elicited in the post-pausal frame sentence.

Under the Sonority-Driven hypothesis, $[a_4]$ should have a different quality from $[a_2]$ because $[a_4]$ is stressed while $[a_2]$ is unstressed. In contrast, the Penultimate hypothesis predicts that $[a_4]$ and $[a_2]$ should have the same quality as both are unstressed.

Focusing on F1, $[a_4]$ overlaps with $[a_2]$, as indicated in Table 1. This suggests that the centralized $[a_4]$ is actually unstressed: if $[a_4]$ is stressed, it should be different from $[a_2]$ in terms of vowel height. The fact that $[a_4]$ overlaps with the unstressed $[a_2]$ is consistent with the hypothesis that stress falls on the penult, rather than on [a].

Vowels		T-value	P-value
a_4: 690.7	a_1: 867.4	-9.072	<0.001
a_4: 690.7	a_2: 666.6	0.970	0.336
a_4: 690.7	a_3: 844.5	-9.219	<0.001
a_3: 844.5	a_1: 867.4	-1.900	0.0624
a_3: 844.5	a_2: 666.6	7.637	<0.001
a_2: 666.6	a_1: 867.4	-13.096	<0.001

Table 1: F1 differences between [a] vowels.

The Penultimate hypothesis is further supported by comparing $[a_4]$ with $[a_1]$ and $[a_3]$. If [a] attracts stress, $[a_4]$ should be identical to the stressed $[a_1]$ and $[a_3]$ according to the Sonority-Driven hypothesis. However, $[a_4]$ differs from $[a_1]$ and $[a_3]$ in that $[a_4]$ has a lower F1 than the stressed $[a_1]$ and $[a_3]$, as shown in Table 1.

As for F2, I find no significant overall difference in F2 for [a] in different positions. Only the pairs [a1] vs. [a2] and [a1] vs. [a3] are found to be significantly different, as shown in Table 2.

Vowels		T-value	P-value
a_4: 1433.2	a_1: 1492	-1.581	0.1189
a_4: 1433.2	a_2: 1436.9	-0.149	0.8818
a_4: 1433.2	a_3: 1416.1	1.061	0.2921
a_3: 1416.1	a_1: 1492	-2.301	0.0246
a_3: 1416.1	a_2: 1436.9	-0.910	0.3663
a_2: 1436.9	a_1: 1492	-2.435	0.0155

Table 2: F2 differences between [a] vowels.

In short, the multiple comparisons of the mean F1 values of [a] confirm the Penultimate hypothesis, instead of the Sonority-Driven hypothesis.

In summary, [a]'s height varies with position: it is more centralized in final syllables regardless of the sonority of the penultimate vowel. This is not consistent with the Sonority-Driven hypothesis, unless stress has no impact at all on vowel height. In contrast, it is consistent with the Penultimate hypothesis. Results from other vowels also support the Penultimate hypothesis: the final vowels are generally more centralized. The reduced vowel space for unstressed vowels is in line with the centralization type of reduction. For discussion on other vowels, see Shih (in prep.).

4.2   *Intensity*   This section explores whether intensity works to distinguish stressed and unstressed vowels in Gujarati. According to Patel & Mody (1960) and de Lacy (2002), [a] has a greater intensity when

it is stressed. Following this prediction, $[a_4]$ in $[C\psi.Ca_4]$ should have a higher intensity under the Sonority-Driven hypothesis but a lower intensity under the Penultimate hypothesis. Figure 2 summarizes the mean intensity values of [a] in various positions. The results are from the data elicited in the post-pausal frame sentence.
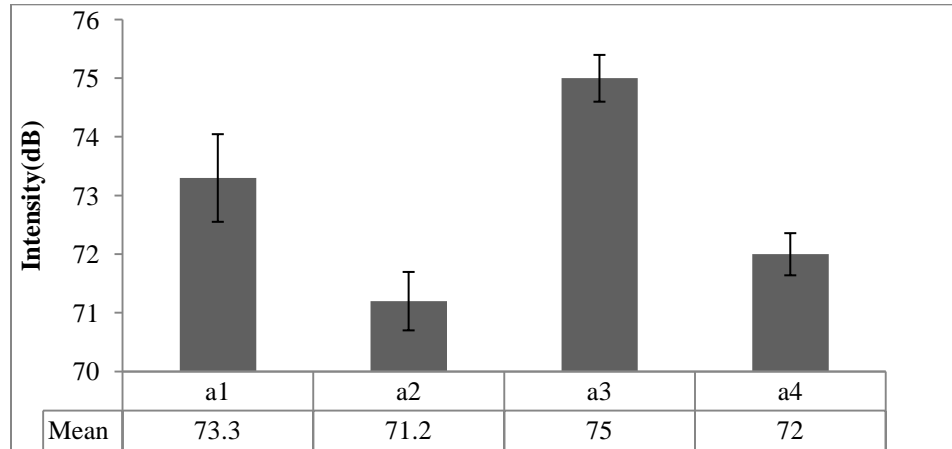

	a1	a2	a3	a4
Mean	73.3	71.2	75	72

Figure 2: Mean intensity values for [a] in different positions.

Crucially, $[a_4]$ has a lower intensity than $[a_1]$ and $[a_3]$ but the same as $[a_2]$: for $[a_4]$ vs. $[a_1]$, t=-2.627, p=0.0105; for $[a_4]$ vs. $[a_3]$, t=-4.441, p<0.001; for $[a_4]$ vs. $[a_2]$, t=0.880, p=0.382. This suggests that $[a_4]$ is actually unstressed if intensity is influenced by stress. If [a] always attracts stress in Gujarati, $[a_4]$ is expected to behave the same as $[a_1]$ and $[a_3]$. However, it is not the case. In addition, recall both hypotheses make the same prediction that $[a_1]$ and $[a_3]$ should be equally stressed. Indeed, no significant difference in intensity is found between $[a_1]$ and $[a_3]$: t=0.784, p=0.436. Therefore, the intensity results indicate stress in Gujarati falls on the penultimate syllable, rather than being attracted by [a].

In sum, the evidence from comparing the intensity values of [a] refute the Sonority-Driven hypothesis but support the Penultimate hypothesis. It is found that vowels in the penultimate position have a greater intensity than their counterparts in the ultimate position. Cross-linguistically, greater intensity functions as an acoustic correlate of stress in many languages, such as English (Lieberman 1960), Pirahã (Everett 1998), Chickasaw (Gordon 2004), Tashlhiyt Berber (Gordon & Nafi 2012), and so on. Like many other languages, Gujarati also uses intensity as a cue to stress.

5   Conclusion

This paper identifies possible acoustic correlates to support/against the claim that stress assignment in Gujarati is sonority-driven. Two hypotheses are formulated based on previous descriptions. The experimental results from vowel quality and intensity favor the Penultimate hypothesis, rather than the Sonority-Driven hypothesis. F_0 and duration were not discussed here, but also broadly support the Penultimate hypothesis (See Shih in prep.).

Importantly, Bowers (in prep.) also provides an acoustic analysis of stress in Gujarati, though using a significantly different experimental design from the one used here. Bowers (in prep.)'s results are entirely consistent with the ones reported here, providing independent support for the claim that Gujarati stress is not sonority-sensitive.

6   Implication: Symmetric Effect

Gujarati is important in sonority-driven stress because it is one of very few cases where stress distinguishes peripheral vowels from each other. The other five cases listed by de Lacy (2004:193) present a variety of phonological and phonetic issues (e.g. all the descriptions are impressionistic, and many have conflicting descriptions). This leaves Gujarati as the most extensively described sonority-driven stress case

with distinctions among peripheral vowels. However, this study has argued that stress in Gujarati is not sonority-driven. As a consequence, three reasonable analytical possibilities immediately suggest themselves.

(7)   Possible scenarios
       Option #1: There is sonority-driven stress, but Gujarati is not a case.
       Option #2: There is no sonority-driven stress at all
       Option #3: Stress can avoid schwa (or central vowels), but cannot make distinctions between
       peripheral vowels.

It is impossible to address option #1 as it relies on evidence that is not available. However, suppose either options #2 or #3 is correct, this consequence presents interesting challenges in analytical frameworks such as Optimality Theory because of the property of symmetric effect.

de Lacy (2002, 2004, 2006) propose that there is a unifying theoretical mechanism that accounts for sonority-driven stress and this same mechanism accounts for interactions at all prosodic levels. Following his work, the sonority hierarchy in (1) can be expressed formally through the form of constraints in Optimality Theory. The symmetric constraint forms and definitions are given schematically in (8). The category foot head (HD) refers to the stressed syllable of a foot while the category foot non-head (NON-HD) refers to the unstressed syllable of a foot.

(8)   Sonority constraints
       a. *HD_α/v
       Assign a violation for every segment in Hd_α that is [wF], where v is a substring of w.
       b. *$NON\text{-}HD_\alpha/v$
       Assign a violation for every segment in non-Hd_α that is [wF], where v is a substring of w.

Crucially, *HD_{Ft}/v cannot exist if there is no sonority-driven stress. Similarly, *$NON\text{-}HD_{Ft}/v$ cannot exist because it can be used to generate the Gujarati system, as demonstrated in (9).

(9)   *$NON\text{-}HD_{Ft}\geq\{a\} >>$ FT-BIN

/hɛɾan/	*NON-HDFt≥{a}	FT-BIN
☞a. hɛ(ɾán)		*
b. (hɛ́ɾan)	*!	

However, *$NON\text{-}HD_{Ft}/v$ is necessary to account for stress-driven neutralization, deletion, metathesis, and coalescence (de Lacy 2006:ch.7). Take stress-driven deletion, for example. This constraint *$NON\text{-}HD_{Ft}\geq\{a\}$ is violated when [a] appears in foot non-head position. So, deleting [a] in this position is an effective way to avoid violating this constraint. This is evident in Lushootseed (Urbanczyk 1996, Gouskova 2003). The low vowel [a] is deleted if it would appear in the non-head of a foot.

(10)   Lushootseed [a]-deletion in the non-head of a foot
       /RED-caq'/ [('cacq')] 'to spear big game on salt water', *[('cacaq')]
       /RED-walis/ [('wawlis)] 'little frog', *[('wawa)lis]
       /RED-laq-il/ [('laʔlqil)] 'be a little late', *[('laʔla)qil]

This pattern can be explained by *$NON\text{-}HD_{Ft}\geq\{a\}$ outranking the anti-deletion constraint MAX (de Lacy 2007). The constraints ALL-FT-L and IDENT[low] must also dominate MAX. Candidate (11d) is the winning candidate because it avoids [a] in non-head position by deleting the [a].

(11)   Right-aligned trochees

/RED-walis/	*NON-HD_Ft≥{a}	ALL-FT-L	IDENT[low]	MAX
a. (wáwa)lis	*!			
b. wawa(lís)		*!*		
c. (wáwə)lis			*!	
☞ d. (wáwlis)				*

So, if either options #2 or #3 are correct, the existence of *HD$_\alpha$/v and *NON-HD$_\alpha$/v is problematic: they seem to be necessary for some sonority-sensitive processes, but have the potentially unattested effect of producing sonority-driven stress. If they are eliminated from CON, there is no way to account for stress-conditioned sonority phenomena other than sonority-driven stress.

The fundamental problem is one of 'too many solutions' (e.g. Blumenfeld 2006). While *(NON-)HD/sonority constraints can motivate vowel reduction and deletion, they should not be permitted to motivate relocation of metrical heads. However, it is not the goal of this article to propose a solution to the 'too many solutions' problem. Instead, the goal was to argue that sonority-driven stress is not as clearly empirically attested as has been argued in a variety of previous work, and in fact may not exist. It has also been to show that eliminating sonority-driven stress is not a trivial task in phonological theories with symmetric effect (e.g. Optimality Theory).

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