Evidence for Sonority-Driven Stress[*]

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Abstract

We argue that there is no adequate evidence for 'sonority-driven stress', building on Shih (2018a,b), and disagreeing with Kenstowicz (1997), de Lacy (2002a, 2004, 2006), and others. More precisely, we argue that there is no phonological mechanism that induces metrical structure to deviate from its default position for reasons that involve the direct interaction of segmental sonority and foot form. After reviewing the history of sonority-driven stress theory, we identify two broad issues with extant evidence: the lack of methodological reliability, and misattribution of cause. We argue that impressionistic descriptions of sonority-driven stress are not reliable, in the technical sense of evidentiary validity. We further argue that apparent sonority-sensitivity in foot form is a side-effect of either allophony or minor syllable behavior.

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Keywords: phonology, metrical structure, sonority-driven stress, sonority, stress, evidence

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[*] We thank the following members of the Rutgers Phonology Laboratory for their key contributions to our understanding of sonority-driven stress: Eileen Blum, Vartan Haghverdi, and Chris Oakden. We would also like to thank the following people for their comments on various precursors to this article: Adam Jardine, Akinbiyi Akinlabi, Matt Gordon, John Kingston, Catherine Kitto, and two anonymous reviewers.

1. Introduction

We inquire as to whether there is adequate evidence for phonological mechanisms that induce metrical structure to deviate from its default position because of requirements that directly involve segmental sonority. The empirical effect of such mechanisms is called ‘sonority-driven stress’ (Kenstowicz 1997, de Lacy 2002a, 2004, 2006, 2007). We argue here that there is no adequate evidence for sonority-driven stress, building on Shih (2018a,b). However, we also argue that sonority can *indirectly* affect metrical structure: if segments of certain sonority are required to have particular moraic configurations and metrical structure is appropriately sensitive to moraic content, then segmental sonority can appear to influence metrical structure.

As an example, de Lacy (2002a, 2006§5.3) argues that Gujarati exhibits sonority-driven stress. The default position for its quantity-insensitive trochaic metrical foot is at the right edge of a Prosodic Word, as illustrated in (1a). However, if an antepenultimate syllable contains the most sonorous vowel – [a] – and the penult has a less sonorous vowel, the foot retracts (1b). Additionally, if the final syllable has an [a] and both the penult and antepenult contain less sonorous vowels, the foot compresses to encompass the final syllable alone (1c).

(1) *Gujarati sonority-driven stress according to de Lacy (2006:233-4)*

(a) (i) [(ˈsa.ɖa)] ‘peasants’

(ii) [ap(ˈwa.na)] ‘to give’

(iii) [mu(ˈba.ɾək)] ‘congratulation’

(b) (i) [(ˈma.ni)to] ‘favorite’

(ii) [(ˈta.dʒe)təɾ] ‘recently’

(iii) [(ˈbrah.mə)ɳo] ‘priestly caste’

(c) (i) [hɛ(ˈɾan)] ‘distressed’

(ii) [ʃi(ˈkaɾ)] ‘a hunt’

(iii) [hoʃi(ˈjaɾ)] ‘clever’

(iv) [pəhɛ(ˈlã)] ‘in the past’

While de Lacy (2002a, 2006) argues that the Gujarati metrical system involves many additional complexities involving vocalic sonority, of present interest is the phonological proposal: it involves a mechanism that penalizes particular configurations of sonority and metrical structure directly. Specifically, the Optimality Theoretic constraint $*\Delta_{Ft}\leq\{e,o\}$ is violated whenever the nucleus of the head syllable of a foot contains a vowel that has sonority less than or equal to the 'peripheral mid vowel' category. When this constraint outranks other constraints on foot location and moraic quantity, it can induce feet to deviate from their default location. This constraint is claimed to be part of a larger family of constraints that directly relate sonority levels to prosodic positions – both heads and non-heads of all categories in the prosodic hierarchy.

The question we pose in this article is whether there is adequate evidence for such phonological mechanisms: Can segmental sonority directly influence the position of metrical feet?

The answer presented below relies on research on sonority-driven stress undertaken by members of the Rutgers Phonology Laboratory over the past several years: Shih (2016, 2018a,b), Haghverdi (2016), and Blum (2018). This research examined cases of sonority-driven stress using experimental methodologies and acoustic analysis. Our finding is that there is no reliable evidence that metrical feet are attracted to or repelled by segments of particular sonority levels, contrary to the theories and claims of Kenstowicz (1997), de Lacy (2002a, 2004, 2006, 2007), and others.

Section 2 discusses the theory of sonority-driven stress with the aim of clearly defining the issue. Section 3 reviews the evidence for sonority-driven stress. It focuses on flaws in this evidence: the unreliability of impressionistic descriptions of the phenomenon, and misattribution of cause to apparent sonority-sensitive in metrical systems.

Section 4 discusses the theoretical implications of our findings.

2. Theory

Research on metrical structure – whether represented as grids or feet – has argued that it is attracted to prosodic and/or morphological edges. Depending on the phonological system, metrical feet may also be affected by syllable 'weight' and underlying marking ('lexical stress') (see Kager 2007 for an overview and references). 'Syllable weight' almost always refers to the structure of the syllable rime – whether it contains a long vowel, diphthong, or (particular type of) coda consonant (see de Lacy 2007 for an overview). Moraic theory identifies syllable weight as moraic content – feet can place strict requirements on moraic content, which can force them to move away from edges, or change shape (Hyman 1985, Hayes 1989, 1995).

A recurring question in metrical theory has been whether there are factors apart from edges and morae that can directly affect metrical feet by forcing deviation in their default location, shape, or the position of their head and non-head syllables. This issue was raised very early in metrical theory research: Prince (1983:71ff) argued that in Passamaquoddy "a syllable containing a full vowel is prosodically heavy; a syllable containing a schwa is light." This analysis preceded moraic theory, so at this point 'weight' was seen as a metrical property of some kind. Crucially, in this analysis, vowel quality can affect heaviness.

Halle & Vergnaud (1987)'s ('H&V') theory also permits segmental properties to directly influence metrical structure. For example, H&V's analysis of Eastern Cheremis invokes a rule "Assign line 1 asterisks to full vowels" (p. 51); this rule effectively distinguishes 'full' vowels from 'reduced' (schwa-like) vowels, and allows the former to be visible to grid formation.

However, to be clear, metrical theories did not focus on non-moraic weight factors. In some overviews of metrical stress theory, there is no significant mention of them (e.g. Kager 1995, 2006), and Hayes (1995:271) called them "a residue of cases", of minor importance. This outlook may explain why the treatment of such factors was rather unconstrained. For example, Halle & Vergnaud (1987)'s approach does not apparently limit the factors that can affect gridmark projection: it is possible that there could be a rule such as "Assign line 1 asterisks to [round] vowels" and "Assign line 1 asterisks only to schwas", both argued to be unattested (e.g. de Lacy 2004).

Hayes (1995:ch.7) (H95) was a major step towards restricting the theory of non-weight metrical influences. H95:272ff's theory involved rules that allowed specific non-weight factors to project marks onto a 'prominence grid', which can then influence stress placement. However, unlike H&V, H95 placed restrictions on how non-quantity factors influenced metrical structure: "stress rules have a choice: […] to refer to a simple criterion of syllable weight (i.e. quantity, under moraic theory) … [or] to employ a rather unconstrained criterion of syllable weight (i.e. prominence…) and have access only to a more impoverished inventory of stress assignment devices." (p.273). In H95:275's sample analysis, prominence only affects foot structure if it respects the form of already-established feet, thus limiting the influence of prominence on foot form.

At the same time as metrical theories were grappling with non-quantity influences on metrical feet, there were two other strands of relevant phonological research. One set of theories involved 'defective schwa': the idea that schwa – or perhaps central vowels more generally – are phonologically different from other vowels. Exactly how they are different depended on the theory – e.g. lack of features, or lack of a mora, or some other defective syllabic constituency (see van Oostendorp 2000 for an overview). Such defective representations could cause schwa to be unfootable, or cause heads to avoid syllables with schwas. Such theories are interestingly different from Halle & Vergnaud (1987) and H95's approaches: there is no *direct* phonological mechanism that prohibits feet or heads from dominating a schwa; instead, schwas have a defective structure (e.g. lack a mora), foot-formation processes are sensitive to that lack of structure, and so feet seem to treat schwas differently from other vowels. Such sensitivity can lead to *inadvertent* sonority-driven stress. For example, if schwas cannot bear a mora in a system, then they cannot head a foot, and so cannot be stressed. We will return to this important distinction of *direct* vs. *indirect* sonority-sensitivity in section 3.2, and argue that there is indeed indirect sonority-sensitivity in metrical systems, but no direct sensitivity.

The other strand of relevant research was 'degenerate syllable' theories. In such theories, syllables are permitted to lack morae in certain circumstances (see Lin 1998, Shih 2018b for overviews). Usually, schwa (or some other reduced vowel) is unable to bear its own mora. While degenerate syllables focused on the syllable and the effects of lack of moraicity on syllable-level phonotactics and processes, the connection to 'degenerate schwa' and metrical prominence theories like H95's is clear: certain vowels – perhaps just schwa – have phonological properties that make them invisible or undesirable to feet. The effect is sonority-driven stress, albeit indirectly caused.

Returning to research on prominence, a significant problem with Halle & Vergnaud (1987) and H95's theories was that they did not provide clear restrictions on which non-quantity factors could influence metrical structure. H&V did not provide any limits. H95:276 list several factors: "heavy syllable quantity, lowness in vowels, high tone, the presence of syllable-final /ʔ/, and the presence or voicing of syllable-initial consonants", and suggests a more general principle to identify such factors: perceptual salience, or "raw prominence", or factors that make syllables "sound louder" (H95:271). However, it is not clear that this list was intended to be exhaustive, and exactly how it related to phonological representation and computation is not immediately clear. H95:271 even entertains (though rejects) the "pessimistic conclusion" that "there are no linguistic universals of interest in this area". H95:276 then suggests that any dimension that influences prominence is universally consistent in the 'direction' of influence: i.e. greater prominence is associated with lower vowels, so no language should show greater prominence of higher vowels.

Kenstowicz (1997) (K97) presented a significant refinement of the theory of non-quantity influences on metrical stress. One of K97's major proposals was to separate H95's non-quantity influences into different categories. Specifically, K97 isolated segmental sonority as a property that influenced metrical structure, distinct from other factors. Later on, de Lacy (2002b) added tone as another property by arguing that there were distinct, specific mechanisms that regulated tone and metrical structure. K97 further provided a restrictive theory of how metrical structure and sonority interact: there are a family of Optimality Theoretic constraints in a universally fixed ranking with the general form *$\text{Peak}_{\text{Foot}}$/*sonority_level* and *$\text{Margin}_{\text{Foot}}$/*sonority_level*. In other words, K97 proposed a phonological mechanism that involved direct influence of sonority values on prosodic structure – both foot heads and non-heads.

de Lacy (2002a, 2004, 2006) then presented a theory that built on K97 (collectively referred to here as 'deL'). It included a more detailed sonority hierarchy, which placed schwa on a level between peripheral high vowels (e.g. [i u]) and high central vowels (e.g. [ɨ ʉ]), given in (2). The symbol '〈' means "is less sonorous than".

(2) *Sonority hierarchy from de Lacy (2002a)*

(a) Consonant sonority

voiceless stops	〈	voiced stops	〈	voiceless fricatives	〈	voiced fricatives	〈	nasals	〈	liquids	〈	glides	〈	…

(b) Vowel sonority

…	high central vowels	〈	mid central vowels	〈	high peripheral vowels	〈	mid peripheral vowels	〈	low peripheral vowels
	ɨ		*ə*		*i•u*		*e•o*		*a*

deL's theory also claimed that the relation between feet and sonority was a smaller part of a much larger theory of the relation between prosody and non-structural factors. The foot-sonority constraints were a part of the family of constraints *π_{Head}/p and *$\pi_{\text{Non-head}}$/p, where π_{Head} is the head element of the prosodic element π, and $\pi_{\text{Non-head}}$ is any non-head element of π (more specifically, deL's theory refers to Designated Terminal Elements – a distinction that is not significant for the present discussion). In these constraints, *p* ranges over any 'prosodic' factor – which includes sonority and tone, but crucially not subsegmental features (e.g. place of articulation, [voice]).

deL's theory provides further restrictions on exactly how the constraints can refer to π properties. For sonority, the constraints penalize lower sonority heads over higher sonority ones, and higher sonority non-heads over lower sonority ones. For example, the constraints on feet and sonority are given in (3). Each constraint mentions a prosodic category – the head syllable of a foot (HDFT) or the non-head syllable of a foot (NON-HDFT). Each constraint also mentions sonority categories; for example, *ɨ* is 'high central vowels, and *i•u* is 'high peripheral vowels' (see (2) above for the other categories) – note that we use '•' here to separate members of the same sonority category, not as an operator of any kind. The constraint *HDFt/*ɨ,ə,i•u* is violated when a head syllable of a foot contains a vowel that is as sonorous as the 'high peripheral vowels' category, or less sonorous.

(3) *Foot-sonority constraints (de Lacy 2004:3)*

(a)	(b)
*HDFt/*ɨ*	*NON-HDFt/*a*
*HDFt/*ɨ,ə*	*NON-HDFt/*a,e•o*
*HDFt/*ɨ,ə,i•u*	*NON-HDFt/*a,e•o,i•u*
*HDFt/*ɨ,ə,i•u,e•o*	*NON-HDFt/*a,e•o,i•u,ə*
*HDFt/*ɨ,ə,i•u,e•o,a*	*NON-HDFt/*a,e•o,i•u,ə,ɨ*

deL was at pains to point out that non-quantity factors could influence feet in a far less restricted way than in H95's proposals. For H95, prominence was essentially a secondary factor and foot conditions always took precedence. For deL, sonority could affect feet just like morae: foot-sonority constraints could force feet to change their head position, size, and location.

So, returning to the Gujarati system in (1), de Lacy (2006:238)'s analysis can be illustrated below. Tableau (4) shows how feet retract from the default rightmost position in so the foot head can fall on a higher sonority vowel. Candidate (b) has default footing, but by doing so violates the constraint on foot heads (*HDFt/*ɨ,ə,i•u,e•o*) because the head of the foot contains an [i]. In contrast, candidate (a) does not violate the head-sonority constraint, but at the expense of aligning the foot's right edge with the right edge of the word (ALIGNFTR). In this way, the head-sonority constraint forces feet to deviate from their default position.

(4) *Gujarati I: Foot movement*

	/manito/ 'favorite'	*HDFt/ɨ,ə,i•u,e•o	TROCHEE	FTBIN	ALIGNFTR
☞	(a) (ˈma.ni)to				*
	(b) ma(ˈni.to)	*!			
	(c) (ˈma)ni.to			*!	* *

Tableau (5) shows another response to the head-sonority constraints. Candidate (b), with the default foot position, fatally violates the head-sonority constraint; so does candidate (c), where the foot has retracted to the left edge. Candidate (d) solves the problem by using an iambic foot, but fatally violates TROCHEE, which requires left-headed feet. The solution – in (a) – is to have a degenerate (monomoraic) foot over the final syllable.

(5) *Gujarati II: Foot reduction*

	/hoʃijaɾ/ 'clever'	*HDFt/ɨ,ə,i•u,e•o	TROCHEE	FTBIN	ALIGNFTR
☞	(a) ho.ʃi(ˈjaɾ)			*	
	(b) ho(ˈʃi.jaɾ)	*!			
	(c) (ˈho.ʃi)jaɾ	*!			*
	(d) ho(ʃi.ˈjaɾ)		*!		

The Gujarati analysis above shows how the head-sonority constraints can force deviation from both the default foot position (rightmost, here), and foot size (i.e. from binary to degenerate).

The idea that sonority (and tone) can directly influence prosodic structure – both its location and size – has gained wider acceptance since the early 2000s (see e.g. McGarrity 2003, Crowhurst & Michael 2005, Carpenter 2006).

We summarized the history and theories of sonority-driven stress above for two reasons. One is to emphasize that non-moraic influences on stress have been the subject of research for a long time, and the theories that have developed are now well defined and extensively explored. The second reason was to allow us define the present goal. We are *not* directly concerned with any stress system where sonority seems to be a factor in the position of size of feet, for, as we have seen above, such systems can be produced by both phonologically direct and indirect means. Our focus is instead on phonological mechanisms that *directly* cause deviation from default metrical position and shape in order to form a different metrical-sonority profile; we call this direct mechanism 'true sonority-driven stress'.

We are also not directly interested in the question "Are there *constraints* of the form $*\pi/p$?" OT constraints are not mechanisms (or 'processes'); a process emerges from the interaction of constraints. For example, the head-sonority constraints can also be used to force metathesis, vowel reduction, and deletion (de Lacy 2007). Our sole concern here is whether there is sonority-motivated deviation from foot position and form that is caused by a phonological mechanism that *directly* relates sonority and feet. Of course, exactly how that mechanism is formally expressed in a particular Generative theory is worthy of examination, and the implications of the lack of true sonority-driven stress can have wide-ranging implications for particular theories – for reasons of space, we must defer exploring those implications here (though see Shih 2018b§2.6.4 for discussion).

As a final comment, we wish to mention the evidence for metrical structure, as presented in the research mentioned above (also see de Lacy 2014 for an overview). Evidence for metrical structure comes from phonological interaction and phonetic realization. For 'phonological interaction', phonological and morpho-phonological processes can refer to metrical structure in their conditioning environments, such as minimal word restrictions, fortition, infixation, and so on; an example is provided for Nganasan in section 3.1 (see de Lacy 2009, 2014 for extended discussion). For 'phonetic realization', 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, Lieberman 1960, Gordon 2004, Gordon & Applebaum 2010, Gordon & Nafi 2012), and longer duration (e.g. Fry 1955, Lieberman 1960, 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). Individuals may differ as to whether they realize foot heads with all or only some of these acoustic factors. Experimental work has included measurements of all or some of these properties; the experiments we cite below examined them all. Impressionistic work is often less clear about what acoustic property is being interpreted as stress; often the location of stress is asserted without mentioning how it was perceived (e.g. Scorza 1985).

So, is there solid evidence for a theory that claims there is a phonological mechanism that directly relates sonority to foot structure, thereby causing foot retraction and degeneration?

3. Evidence

We cannot demonstrate that sonority-driven stress does not exist; we can only show that there is currently no adequate evidence for it. We divide the issue into two parts here. One involves 'reliability': a technical term that refers to whether a measurement device produces consistent results. Section 3.1 argues that the majority of evidence for sonority-driven stress is either produced by devices that are either unreliable, or whose reliability cannot be determined. The other part, in section 3.2, is about the causes of apparent sonority-sensitivity. We argue that there are several such causes, and so the need for direct mechanisms involving influence of feet by sonority have not been conclusively demonstrated.

3.1 Reliability

We use the term 'reliability' here in its technical sense: a method is reliable if it can be applied repeatedly to the same data and produce the same result (e.g. Ray 2009).

For sonority-driven stress, the vast majority of evidence comes from impressionistic descriptions, reported in grammars and journal articles (see Shih 2018b:ch.5). 'Impressionistic descriptions' are here considered to be any description that involves a human perceiving and reporting the position of stress, unaided by mechanical analytical devices (e.g. spectrographs, pitch trackers). For example, de Lacy (2002a)'s description of Gujarati stress involved a human – de Lacy – listening to and transcribing the speech of an individual, and marking where de Lacy believed stress fell. de Lacy also recorded the speech and later listened to the recordings, and made changes to the transcriptions if he believed he had erred in his initial transcription. de Lacy did not analyze the recordings using any acoustic analysis devices. So, de Lacy (2002) is the report of de Lacy's perceptual impressions of where stress fell – i.e. an 'impressionistic' description. We note that the large majority of descriptions we have consulted do not state outright that they are impressionistic; we infer that they are due to the lack of information about the methodology used to obtain data, and that the impressionistic approach is the dominant method taught and used in linguistic field research (see e.g. Cheliah & de Reuse 2011§8.3.2, c.f. Ladefoged 2003).

So, for sonority-driven stress, are impressionistic descriptions of sonority-driven stress reliable? In this section, we focus on the reliability of impressionistic descriptions specifically for those cases involving peripheral vowel distinctions.

3.1.1 Au We can address the question of reliability (with caveats discussed below) by examining cases where there have been multiple descriptions of the same sonority-driven stress system. An instructive case is Au (Torricelli > Wapei-Palei > Wapei; Sandaun Province, Papua New Guinea). A series of articles and books – Scorza (1973, 1976, 1985, 1992) – provide descriptions of the stress system. S73's description is as follows:

(6) Au stress (S73)

"[Stress] usually occurs on [the] third syllable of a four syllable word, the first syllable on [sic] a three syllable word, and alternates from syllable to syllable on two syllable words, that is from initial to final depending on the word. Stress is recognized by loudness and high pitch."

S73's description does not admit of a simple characterization in terms of standard metrical theory. It perhaps involves building trochees from left to right, with the second syllable being the head (producing [(ˈσσ)σ] and [(ˌσσ)(ˈσσ)]), with lexical stress in disyllables. It certainly does not involve sonority.

However, S76/S85 presents a different description: "Stress normally occurs on the first syllable of a word" (contrary to S73's claim that it falls on the third syllable in 4-syllable words, and variably on disyllables). Additionally, S76/S85 claims the following:

(7) Au stress (S76/S85)

(a) The vowel /ɨ/ is never stressed unless the only vowels in the word are /ʌ/ or another /ɨ/ (e.g. [k-ɨˈsawɨn] 'he-hides'; [hɨˈhi] 'ironwood'; [ˈmɨtɨk] 'man')

(b) The vowel /ʌ/ is never stressed unless the only other vowels are /ɨ/ or another /ʌ/ (e.g. [kʌˈwat] 'he-gives', [ˈnʌpʌɾʌ] 'dog')

The additional clauses from S85 mean that Au has a sonority-sensitive system. It is possible that the non-peripheral vowels /ʌ/ and /ɨ/ are the two least sonorous vowels – the others are the peripheral /i u o a aː/ (S85:219). So, S85 seems to describe a classic sonority-driven stress system: stress falls initially, unless the initial syllable contains a low sonority vowel: e.g. [k-ɨˈsawɨn], [kʌˈwat].

Finally, S92 contains another description: “Stress usually occurs on the first syllable of the word, but may change under certain morphophonemic considerations.”[1]

S73, S76, S85, and S92 do not mention machine acoustic analysis, suggesting that all of the descriptions were impressionistic, from either direct fieldwork or recordings made in the field (S73:165-166). It is likely that the stress analyses in S73 and S76/85 involved consultation of the same data as the same fieldwork dates and consultants are mentioned (S73:165-6 cf. S76:5 cf. S85:215). In other words, the same person analyzed the same data twice. This homogeneity is important because both the device (Scorza himself) and the data were kept constant, so allowing us to ask whether the device is reliable.

It is important to emphasize that ‘reliable’ here is a technical term, and does not carry any emotional weight or judgement with it. It simply refers to whether a particular device and methodology produces the same result given the same data; the device just happens to be a human here, but we could – and should – ask the same of any device used in phonological analysis (e.g. microphones, algorithms, software). In this sense, it is clear that the device – i.e. Scorza – is not reliable. The descriptions reported in S73 and S76/85 are significantly different, even though the data was the same. Not only is there difference in whether Au is sonority-sensitive or not, but there are differences in where stress falls both on four syllable words (S73: the third syllable; S76/S85: the first syllable), and where stress falls on disyllables (S73: either syllable; S76/85: the first syllable). It is unclear whether S92 is a further independent description by Scorza, or an incomplete summary of previous descriptions; if it is a new description, it presents yet a different description, ignoring the sonority effects in S76/S85.

There is an obvious problem with the reasoning presented above. The assumption was that the device – i.e. Scorza – was the *same* in 1973 as in 1976, 1985, and 1992. However, there may have been profound changes in Scorza’s knowledge and skill over that time, and perhaps even physical changes relevant to perception. Unfortunately, there are few clues in the publications to be sure. It is possible that the device *was* reliable (and accurate,

[1] Scorza’s later works do not mention the fact that earlier works differed in their stress descriptions: e.g. S85’s stress section does not mention S73’s stress description, even though S85 includes S73 in its bibliography. It is possible that the lack of mention is merely due to the limited space given to discussion of stress.

and adequately precise) at one point in time, but not at others. However, this consideration raises a profound problem when relying on impressionistic descriptions: how can we ever determine reliability if we can ascribe variation in description to change in the describer, or differences between devices (e.g. people)? This problem is particularly acute because impressionistic descriptions typically do not describe the methods used. For example, none of the Au sources cited above give details about the type of elicitation methods used, the elicitation environment, speech-relevant properties of the experimental subjects, and – crucially – about the nature of the perceptual device itself – i.e. Scorza.

In many cases, it was also not possible to see how the author arrived at their generalizations because either no data was presented to support the claim, or the data presented did not cover all possible word lengths and syllable shapes. For example, S73 provides stress generalizations but no data annotated for stress in any part of the article, which is 22 pages long. S85 provides a total of 10 words annotated for stress in 273 pages (all on p.219). Of these 10 words, only three show stress on a non-default position: [k-ɨˈsawɨn] 'he-hides', [k-ʌˈwat] 'he-gives', and [k-ʌˈkintɨp] 'he-steals' (S76 provides an additional relevant word: [hɨˈhi] 'ironwood'). In other words, the evidence for the claim that Au has sonority-driven stress is three words. We do not know how representative these words are of words of this form (at worst, they may be suppletive forms). Strictly speaking, they only show that [a] and [i] attract stress away from [ɨ] and [ʌ] – no data is provided that shows the other vowels [u o aː] attracting stress away from these central vowels. There is also no data that shows the relationship between [ɨ] and [ʌ]: while [ˈmɨtʌ] 'woman' indicates that [ʌ] does not attract stress away from [ɨ], no word is provided that shows that [ʌ] fails to attract stress away from [ɨ] (i.e. no data shows whether Au treats [ʌ] as more sonorous or the same in sonority as [ɨ]). A final point is that the three words are all verbs, and all have the third person singular masculine prefix; it is possible that part of speech, morphological structure, or particular affixes affects stress, so one might view the examples as beign inadequately morphologically diverse. Of course, this point about data broaches a much broader issue of how to identify adequate data in support of generalizations – a topic that takes us too far afield (though see de Lacy 2009, 2014 for relevant discussion).

The descriptions of Au stress at least force us to the conclusion that *not all impressionistic descriptions* are accurate. Some might be accurate, but the variation in the Au descriptions indicate that some are not. Importantly, we have no straightforward way of telling the two apart – i.e. was S73 right, or S76/85, or S92? To put it another way, based on the descriptions we have available to us, does Au have sonority-driven stress or not? There is no reliable evidence either way.

3.1.2 Gujarati Au is a remarkable case because the same person described it at different times. It is far more usual for *different* people to describe the same case over a period of time. So, we can ask the question of reliability in such multi-device contexts, too.

The most extensively described sonority-driven stress case of which we are aware is Gujarati (Indo-European>Western Intermediate Indo-Aryan; spoken in Gujarati province, India and elsewhere): thirteen descriptions of Gujarati stress are known to us, including Shih (2018a). It is possible that all of the descriptions are independent – few of them mention the other descriptions, and when they do (e.g. de Lacy 2002a) it is to point out differences rather than similarities. If humans are broadly reliable devices in regard to the impressionistic description of sonority-driven stress, we would expect a fairly strong homogeneity in the descriptions. Instead, there is remarkable divergence on almost all metrical dimensions.

Focusing on just the influence of sonority on stress, Turner (1921) and Master (1925) (for disyllables) claim that Gujarati stress falls on a fixed position – there is no sensitivity to sonority. In contrast, Cardona (1965) claims that [a] attracts stress away from other vowels, and both [i] and schwa repel it onto more sonorous vowels. Mistry (1997), de Lacy (2002a) and Cardona & Suthar (2003) claim that – for disyllables – stress does *not* avoid schwa (cf. Cardona 1965), while de Lacy (2002a) also claims that stress does not avoid [i]. While several descriptions say that [a] attracts stress away from other vowels, Adenwala (1965) groups [a] with the mid vowels, and Campbell & King (2011) group [a] with all of the peripheral vowels. Table 1 summarizes the role of sonority in the descriptions, grouping vowels according to how the stress system purportedly favors them in the attraction of stress.

Source	Categories
Penultimate stress	
Turner 1921 Master 1925: 2σ	$\boxed{\text{a ɛ ɔ e o u i ə}}$
Sonority-driven stress	
Mistry 1997 de Lacy 2002a: 2σ Cardona & Suthar 2003: 2σ & 3σ	$\boxed{\text{a}}$ $\boxed{\text{ɛ ɔ e o u i ə}}$
Cardona 1965: 2σ de Lacy 2002a: 3σ Doctor 2004: 2σ Schiering & van der Hulst 2010: 2σ & 3σ	$\boxed{\text{a}}$ $\boxed{\text{ɛ ɔ e o u i}}$ $\boxed{\text{ə}}$
Cardona 1965: 3σ Doctor 2004: 3σ	$\boxed{\text{a}}$ $\boxed{\text{ɛ ɔ e o u}}$ $\boxed{\text{i}}$ $\boxed{\text{ə}}$
Adenwala 1965: 2σ	$\boxed{\text{a ɛ ɔ e o}}$ $\boxed{\text{u i}}$ $\boxed{\text{ə}}$
Campbell & King 2011 Modi 2013: 2σ	$\boxed{\text{a ɛ ɔ e o u i}}$ $\boxed{\text{ə}}$

Table 1. *Sonority distinctions in descriptions of Gujarati stress*

Table 1 does not do justice to the diversity of the descriptions. There are also disagreements over whether syllable shape affects stress (e.g. Masica 1991 vs. Cardona & Suthar 2003). Other descriptions of syllable shape mainly focus on [ə]: for some descriptions, when [ə] occurs in a closed syllable, it does not repel stress (Cardona 1965, Doctor 2004, Schiering & van der Hulst 2010).

Interestingly, outside theoretical works (de Lacy 2002, Shih 2018a,b, Bowers 2019), there is very little explicit discussion – or even acknowledgement – of the diversity and contradictions in the Gujarati stress descriptions. For example, in the most recent descriptive work, Modi (2013§4.7), no previous description is mentioned. We are not sure what to conclude from this lack of explicit discussion except to note that stress is not unique – each descriptive work we examined had very little discussion of other descriptive works for most of the topics they covered (other than mentioning previous research in their bibliographies). We do not know whether it is standard practice for descriptive works to avoid explicitly mentioning previous work as we know of some cases to the contrary (e.g. Dunn 1999's grammar of Chukchi, which discusses previous research in detail).

At this point, we are faced with a similar question to that for Au: Does Gujarati have sonority-driven stress or not?

Of course, there are profound problems in assuming that we can compare the various Gujarati stress descriptions. For one thing, it is not clear that any of the descriptions were describing the same peoples' speech; it is possible that the variation in descriptions is due to different dialects (although Cardona 1965 and de Lacy 2002a both specifically mention the Ahmedabad dialect). It is also possible (and in fact almost certain) that the dialects have changed over time, from Turner (1921) to Modi (2013). As with Au, it is also not clear that every description was produced by an equally accurate device – the descriptions do not provide details as to *how* they arrived at their descriptions, and so it is impossible to be sure that equivalent methods were used.

However, raising such questions broaches a profoundly worrying issue: if invoking dialect differences, change over time, and variation of accuracy in linguistic devices allow us to put concerns about reliability aside, then we can never ask about the reliability of impressionistic descriptions. If we cannot be sure that our devices are reliable then they are effectively worthless for scientific research.

We conclude by mentioning that there are two recent studies of Gujarati stress that are not impressionistic – Shih (2018a,b) (S18) and Bowers (2019). S18 reports the result of the acoustic analysis of a production experiment. Intensity, F0, F1, F2, and duration were measured to see if there were any differences in disyllables with the form [CVCa] vs. [CaCV] (where V is not [a]). According to most of the impressionistic descriptions of Gujarati, [CVCa] should have final stress while [CaCV] should have initial stress. However, S18 found no evidence that stress was any different in these words: both words were consistent with having penultimate stress. We repeat the results for vowel quality (F1 and F2) from Shih (2018b) in Figure 1 below.

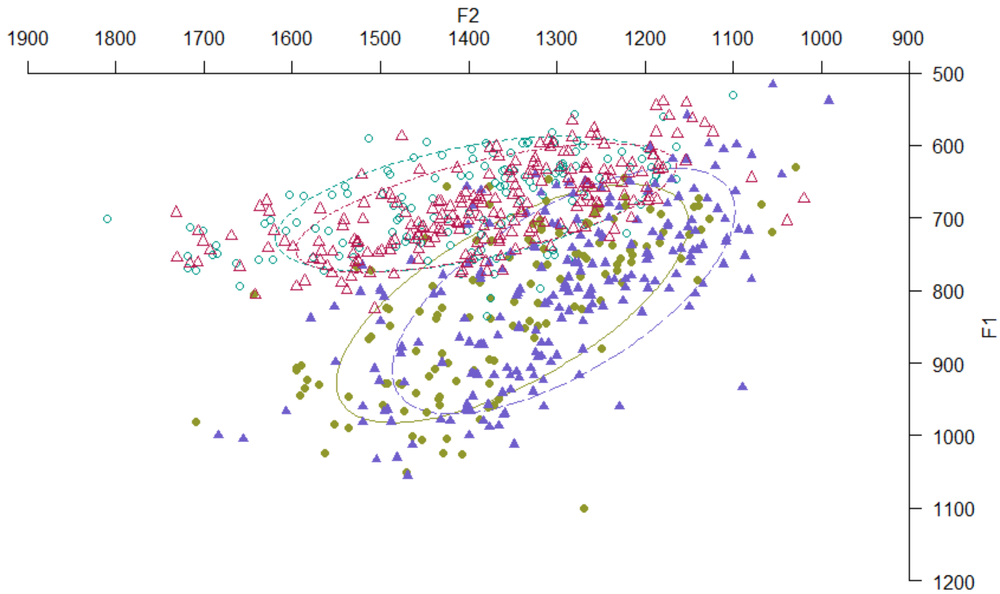

Figure 1. Gujarati vowels in post-pausal context.
• [Cá̲Ca]; ▲[Cá̲CV]; △ [CVCá̲]; vs. ○ [CáCa̲]

If [a] attracts stress away from non-[a] vowels, and vowel quality reflects stress (as claimed by Cardona 1965, de Lacy 2002a), we would expect the quality of [a] to be the same in [Cá̲Ca] (•), [Cá̲CV] (▲), and [CVCá̲] (□) because they should all contain stressed [á]s, in contrast to [CáCa̲] (○), which contains an unstressed [a]. However, the results group the [a]s based on their position, not their stress: [a] in initial syllables (• and ▲) has a distinct F1 from [a] in final syllables (○ and □). If stress has anything to do with F1, the results above indicate that the penult is always stressed, regardless of where [a] is. We refer the reader to Shih (2018a) for detailed statistical models that demonstrate the statistical significance of the assertions made above.

In other words, comparison of impressionistic descriptions with S18's experiment and acoustic analysis shows significant disagreement in terms of the stress-attracting powers of [a] in Gujarati. Bowers (2019) also presents an acoustic analysis of production experiments, independent from Shih (2018a)'s research. Bowers (2019) concluded that F0, F1/F2 and duration indicate that there is a difference between initial and non-initial syllables, but the results "failed to find clear acoustic correlates of sonority-driven stress as described by de Lacy (2002; 2006)" (p. 25).

If acoustic analyses of sonority-driven are presumptively assumed to be more reliable than impressionistic descriptions, then it is potentially a cause for concern that so many descriptions reported that [a] attracted stress away from lower sonority vowels. We discuss the issue of how impressionistic approaches could produce errors below.

3.1.3 Nganasan Like Gujarati, there are multiple descriptions of Nganasan stress: Helimski (1998, personal communication), Castrén (1854), Prokofjev (1937), Hajdú (1964), Tereshchenko (1979), Lublinskaya et al. (2000), de Lacy (2002a), and Vaysman (2009) (Uralic > Samoyed; Siberia, Russia). de Lacy (2004) (deL) describes an elaborate sonority-driven stress system. The description was based on previous descriptions and on the author's impressions of audio recordings: default footing involves a right-aligned quantity-sensitive trochee: e.g. [car(ˈkiː)] 'worn out', [hu(ˈtaruʔ)] 'of the houses'. However, stress retracts to the antepenultimate syllable if it contains one of [a e o] (i.e. high and mid peripheral vowels) and the penult contains one of [i y u ə ɨ] (i.e. high peripheral vowels and central vowels).

It is worth noting that Tereshchenko (1979)'s description does not mesh perfectly with deL's. Tereshchenko (1979: 41) states that stress on trisyllabic words is unpredictable, though deL claims that most of Tereshchenko's data fits with deL's description. Helimski (1998)'s description also does not clearly match deL's: Helimski (1998) cites [koˈruðə] 'houses', not *[ˈkoruðə] as expected in deL's analysis. Helimski (1998)'s description also diverges from deL's in other important ways involving optionality and syllable shape: "[Default stress] is optionally violated by the retraction of stress from a high vowel or *ə* to the vowel (usually an open one) in the preceding syllable: *baru̲sʲi ~ ba̲rusʲi* 'devil') (Helimski 1998:486).

The most recent description of Nganasan (also based on the Avam dialect) is Vaysman (2009)'s (V09). V09's and deL's descriptions agree about the default position of feet. However, there is a crucial difference: deL reports that feet retract from a penultimate [i y u ə ɨ] onto a preceding low or mid peripheral vowel, while for V09 it only retracts from a central vowel [ə ɨ] (V09§2.2.1.2). So, while 'salmon' is [ba(ˈkunu)] for V09:28, it would be [(ˈbaku)nu] for deL; similarly 'clay (locative)' is [sa(ˈðutə)nu] for V09, but is predicted to be [saðu(ˈtənu)] for deL.

The apparently minor disagreement between V09 and deL has an outsized importance. deL presents Nganasan as crucial evidence for the theory of stringent sonority-foot constraints (all other sonority-driven stress systems can be accounted for using constraints with fixed ranking, as shown in K97). With V09's description, Nganasan potentially loses its power to make the theoretical distinction claimed by deL. Apart from the theoretical significance of Nganasan, we are left with a disagreement of impressionistic descriptions, with apparently no way to resolve them.

However, V09 does provide an additional relevant diagnostic. As de Lacy (2008) discusses, metrical evidence can come from many sources, including metrically-sensitive processes like fortition. Relevantly, V09 describes a metrically-sensitive consonant gradation process. However, V09:21 notes: "the foot structure that is marked by gradation **does not match** the stress pattern, namely the placement of the primary stress and its shifts from [ə] and [ɨ] leftwards." (emphasis from original). Consider the 2nd person dual suffix *-ti*/*-ði* in (8). The 2nd person dual suffix is [ti] when foot-internal, and [ði] foot-initially (a specific example of a more general consonant gradation process). This analysis works only if trochaic feet are constructed from left to right, as the footing indicates. However, the default primary stress falls on the penultimate syllable. This places the primary stressed syllable at odds with the trochaic foot parse needed for consonant gradation, as shown in (8a,b vs. c,d).

(8) *Consonant gradation in Nganasan (Vaysman 2009: 45-46)*

(a) [(ˈko-ti)]	'your (du.) ear'
(b) [(ˌbaku)(ˈnu-ti)]	'your (du.) salmon'
(c) [(haˈhi)-(ði)]	'your (du.) wild deer'
(d) [(ˌkərï)(gəˈʎi)-(ði)]	'your (du.) march'

In other words, the evidence for metrical structure from phonological processes does not support either deL's or V09's impressionistic claims about primary stress location.

In short, Nganasan presents phonological evidence that does not support the claims about primary-stress placement. While it is possible that Nganasan has dual disjoint metrical tiers (e.g. Parker 1998), at the very least consonant gradation provides no support for the claims about sonority-driven primary stress, and potentially contradicts it. What we see for Nganasan, then, is not only disagreement in impressionistic descriptions of stress, but conflicting results using different methodologies – impressionistic description, and metrically-sensitive allophony.

3.1.4 Armenian Haghverdi (2016) reports the results of acoustic analysis of a production experiment on Eastern Armenian stress (Indo-European > Armenian; spoken in Armenia and other locations). Unlike Gujarati and Nganasan, there is unanimous agreement among impressionistic descriptions that stress falls on the final syllable unless it is a schwa, in which case it falls on the penult (which is never a schwa when the final syllable is also a schwa) (Khachatryan 1988, Vaux 1998, Sakayan 2007, Dum-Tragut 2009). Thanks to a rich inventory of suffixes, stress can be usually observed to advance rightwards in a word, as long as the final syllable is not schwa. Compare the forms and their stress in (9), all of which have the same root.

(9) *Eastern Armenian stress* (Haghverdi 2018:1)

[ɑ.ˈnuʃ]	'sweet'
[ɑ.ˈnu.ʃ-ə]	'the sweet'
[ɑ.ˈnu.ʃ-ət]	'your sweet'
[ɑ.nu.ˈʃ-i.t͡sʰ-ət]	'from your sweet'

Armenian stress is apparently quite different from Nganasan, Au, and Gujarati because it involves several impressionistic descriptions that all agree with each other. It seems that – at least for Armenian sonority-driven stress – the detection devices (i.e. humans) are reliable.

However, Haghverdi (2016)'s (H16) acoustic analysis results differ from the impressionistic descriptions'. H16 found no meaningful difference between final full vowels and schwa in terms of duration, intensity, and quality. In fact, there were no significant differences between full vowels regardless of whether they were in putative stress or non-stress position. The only significant difference was in F0, with H16's result repeated in Figure 2. The Figure shows the results of measuring, then normalizing, F0 and duration in words with the shape CVCVC (where V is not schwa) compared with CVCəC words, in both focused and non-focused contexts.

In Eastern Armenian, CVCVC words should have final stress and CVCəC words should have initial/penultimate stress. Pitch is commonly claimed to peak over the stressed vowel, so we would expect CVCəC to have an early F0 peak, while CVCVC should have a late F0 peak. However, all of the forms in H16's results have an F0 peak over the final vowel, and the F0 peak is even at the same normalized level.

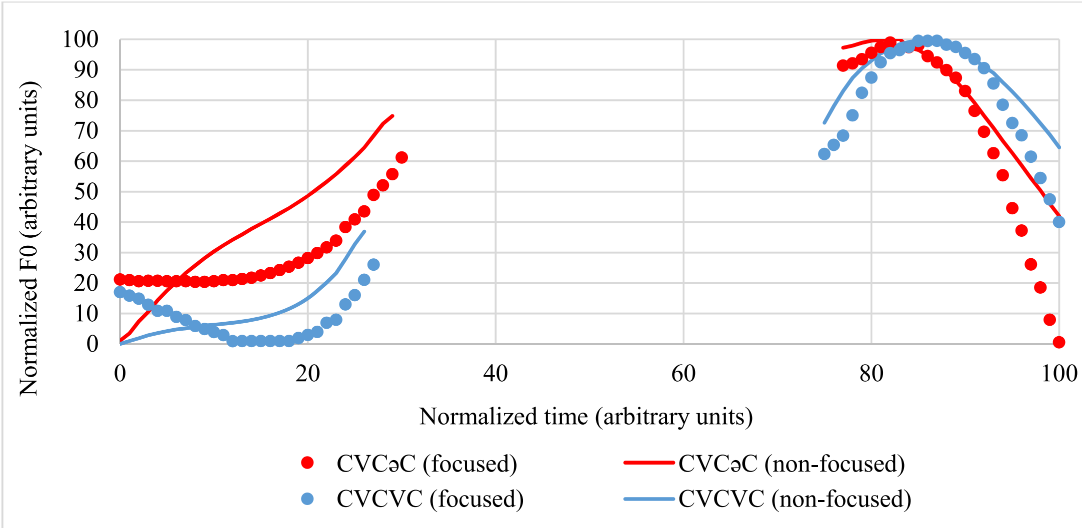

Figure 2. Eastern Armenian normalized F0 contours (adapted from H16, with F0 interpolation removed).

In other words, if stress is marked by the F0 peak, all words have final stress.

What could have caused impressionistic descriptions to claim that schwa repels stress? There are two possibilities. One is that the describers were familiar with languages that signaled stress differences through vowel reduction (e.g. many dialects of English). As 'schwa' signaled lack of stress in the describers' L1, it is possible that this led them to classify Armenian schwa as 'stressless'. Another option relates to F0. If the describers were familiar with languages where F0 peaks over word- or phrase- stressed syllables (e.g. English, again), the F0 results seen in Figure 2 might provide some explanation. Notice that F0 over a penultimate vowel preceding a schwa (in red) is higher than when a full vowel precedes a full vowel (in blue). The reason for this F0 difference is incidental: schwa is relatively shorter than other vowels, and so the pitch peak in [CVCəC] words is closer to the initial V than in [CVCVC] words. Consequently, the interpolated F0 is higher over the first vowel in [CVCəC] words. However, this incidental difference in F0 – perhaps coupled with the association of stress with stresslessness – could have led to the misperception of stress over full vowels in [CVCəC] words.

The issue that Haghverdi (2016)'s study broaches is that of 'cross-method' reliability: do impressionistic methods get the same results as production experiments with acoustic analysis? The answer – from both Eastern Armenian and Gujarati (and Munster Irish, below) – is no. If we assume that acoustic analysis of controlled experiments is likely to be more reliable than impressionistic methods, then we are at least left with uncertainty for Eastern Armenian. In other words, is there clear evidence that Eastern Armenian involves sonority-driven stress? Even though the impressionistic descriptions all agree, the fact that their results disagree with those of a potentially more reliable methodology cast the issue into doubt.

3.1.5 Reliability What about the reliability of descriptions of other sonority-driven stress systems? We list all the sonority-driven stress systems we know that involve peripheral vowel distinctions in Table 2 below. We judged a case as 'sonority-driven stress' if stress was reported to appear on a non-default syllable due to its having a particular vowel quality or sonority. For example, Ross (2009: 762) reports that the default stress position in Takia is the final syllable, as in [ta.ˈman] 'her/his father'. However, stress occurs on the rightmost or only [a] in the word, as in [ˈna.nun] 'her/his child' and [ˈŋa.sol] 'I fled'. If there is no [a], stress occurs on the last or only [e] or [o], as in [kr.ˈŋen] 'his/her finger/toe', [u.ˈsol] 'you (SG) fled', [ˈpe.in] 'woman'. Based on the description provided by Ross, the sonority distinctions that stress is sensitive to in Takia are therefore | a > e o > i u |. The table excludes systems in which the only stress-sensitive avoidance involves schwa; we discuss such cases below.

Language	*Version*	*Sonority distinctions for stress*
Au	(a) Scorza (1973, 1992)	None (see above)
	(b) Scorza (1976,1985)	a: a o u i > ɨ, ʌ
Cowichan	Bianco (1998)	a e > i > ə
Gujarati	See section 3.1.2; Shih (2018a, b)	Uncertain – see section 3.1.2; Shih (2018a, b)
Harar Omoro	Owens (1985) de Lacy (2002a)	a > ʌ, ɔ, ɨ
Kara	(a) Schlie & Schlie (1993)	a > ɛ ɔ e o ɪ ʊ i u ə
	(b) Schlie (1996)	a > ɛ ɔ e o ɪ ʊ i u ɐ
Kobon	(a) Davies (1981)	a au ai > o e u i > ə ɨ
	(b) Kenstowicz (1997)	a > e o > i u > ə > ɨ (based on data from Davies 1981)
	(c) Davies (1980)	Penultimate stress
Ma Manda	Pennington (2013)	a > e o > ə > i u > ɨ
Mordwin	Tsygankin & Debaev (1975) Kenstowicz (1997)	e o ä a > i u ɨ

Nanti	Crowhurst & Michael (2005)	a > e o > i
Nganasan	(a) de Lacy (2002a, 2004)	a e o > i y u ə ɨ
	(b) Vaysman (2009)	a e o i y u > ɨ > ə
Pichis Ashéninka	Payne (1990)	a e o > i
Takia	Ross (1995, 2002, 2009)	a > e o > i u
Umutina	Telles (1995), Wetzels & Meira (2010), Wetzels, Telles & Hermans (2014)	a > ɛ ɔ e o > i u ɨ (based on data from Wetzels, Telles & Hermans (2014)) *or* a > ɛ ɔ > e o > i u ɨ
Yessan-Mayo	Foreman & Marten (1973)	a > ɔ, ʌ , ɨ
Yimas	Foley (1991)	a > i u > ɨ

Table 2. Languages with peripheral vowel distinctions.[2]

On its face, the table above seems to present an impressive array of cases that support the claim that sonority-driven stress exists. However, many of the descriptions come from a single source, so there is no way to evaluate their reliability in the context of that particular language. Of course, there is an indirect way of evaluating reliability: i.e. to show that the methods used in the particular description were reliable when used elsewhere. However, this is impossible to do in practice because none of the descriptions discussed their methods in adequate detail, or at all. Even if 'impressionistic description' always involved exactly the same procedure, we have seen that it is unreliable from the Au, Gujarati, and Eastern Armenian case studies discussed above.

The best described cases are Gujarati and Nganasan, but we have seen that the impressionistic descriptions disagree with each other, and with experimental results in the case of Gujarati. Of the 15 languages cited above, eight have multiple descriptions: Au, Gujarati, Mordwin, Kara, Nganasan, Kobon, Harar Omoro, and Umutina. Disagreements about stress assignment were found in five out of these seven: i.e. Au, Gujarati, Kara,

[2] Language (alternate name(s); iso 639-3 code): Classification; Location: Au (avt): Torricelli > Wapei-Palei > Wapei; Sandaun Province, Papua New Guinea. Cowichan (Halkomelem; hur): Salish; British Columbia, Canada. Gujarati: Indo-European>Western Intermediate Indo-Aryan; Gujarati province, India and elsewhere. Harar Oromo (Eastern Oromo; hae): Afro-Asiatic > East Cushitic; Afar, Harari, Oromia and other regions. Kara (Lemakot; leu): Oceanic >Meso Melanesian; New Ireland, Papua New Guinea. Kobon (kpw): Trans-New Guinea, Madang; Madang province, Papua New Guinea. Ma Manda (skc): Trans-New Guinea >Finisterre; Papua New Guinea. Mordwin (Erzya; myv): Uralic > Mordvin; Russia. Nanti (cox): Maipurean >Asháninga Campa; Peru. Nganasan (Tavgi Samoyed; nio): Uralic >Samoyed; Siberia, Russia. Pichis Ashéninka (cpu): Maipurean >Asháninga Campa; Peru. Takia (tbc): Oceanic >North New Guinea >Nuclear Bel; Papua New Guinea. Umutina (Umotina; umo): Bororoan; Mato Grosso, Paraguay. Yessan-Mayo (yss): Sepik >Tama; Papua New Guinea. Yimas (yee): Ramu-Lower Sepik >Karawari; Papua New Guinea.

Nganasan, and Kobon. Even more significantly, Raisin (2017) argues that the data for Kobon presented in the primary sources does not support the generalizations made about sonority-driven stress by Kenstowicz (1997) and others.

It is therefore difficult to evaluate what the table above actually means in terms of evidence. Potentially it means nothing. We have also seen for Eastern Armenian that mere agreement among impressionistic descriptions is not necessarily probative: all impressionistic descriptions of Eastern Armenian agreed with each other, but they did not agree with experimental results.

As Haghverdi (2016) and Shih (2018a,b) discuss, it is possible that the table above simply shows that humans with particular linguistic backgrounds interpret certain perceptual impressions as 'sonority-driven stress'. One incidental phonetic property of different vocalic sonority levels is duration: higher sonority vowels have longer inherent duration than lower sonority vowels (Peterson & Lehiste 1960). Absent any of a listener's expected perceptual cues to stress, it is possible that listeners will employ these inherent duration differences as significant, leading to the perception of sonority-driven stress. Another possibility was discussed above for Eastern Armenian: schwa is often shorter than other vowels, and so interpolated F0 might be affected by the presence of schwa in a word, leading to the misperception of stress by a perceiver who is used to attending to F0 as a stress cue. Dobrovolsky (1999:541) discusses a similar case for Chuvash. There is no perceptual cue for stress in words that only have reduced vowels; however, Dobrovolsky suggests: "Chuvash disyllabic words … are characterized by an intonation drop across the first vowel early in the word. I suggest that this is what is interpreted as "stress," given a lack of other robust stress measures on the word." For relevant discussion, see Tabain *et al*. (2013) and Bowers (2019).

3.2 Misidentification of cause

While some cases of apparent schwa avoidance may be misdescribed (e.g. Eastern Armenian in section 3.1.4, above), we argue that feet *can* avoid schwa. However, the cause of such avoidance is a side-effect of representational differences between schwa and other vowels, and not because there are direct restrictions on schwa and foot elements.

• Paiwan and non-moraic schwas

Shih (2018b) provides a detailed example from Piuma Paiwan (Austronesian > Paiwan; spoken in Paiwan, Taiwan). We only briefly summarize the results of S18's experiment and acoustic analysis here as our goal is to compare them to the impressionistic descriptions'.

Descriptions of Piuma Paiwan have reported a sonority-driven stress system that is sensitive to the distinction between schwa and peripheral vowels (Chen 2009a,b, Yeh 2011). The default position for stress is on the penultimate syllable (10a). However, stress falls on the final syllable if the penult contains a schwa (and the final syllable does not) (10b). If both the penult and final syllable contain schwa, stress falls on the final syllable.

(10) *Piuma Paiwan's sonority-driven stress according to Chen (2009a, b) and Yeh (2011: 116-117)*

(a) Default stress on the penultimate syllable

[ˈkaka]	'sibling'	[ˈgadu]	'mountain'
[ˈvuvu]	'grandparents'	[ˈtsaviʎ]	'year'
[ˈɭigim]	'needle'	[ˈtutaŋ]	'aluminium'
[tsaˈʎiŋa]	'ear'	[ˈpiku]	'elbow'
[viˈtsuka]	'stomach'	[ʎaˈvatsaq]	'horsefly'
[ˈragəd]	'pebble'	[ˈtidəq]	'interval'
[maˈqipər]	'unlucky'		

(b) Stress the final syllable if the penult contains a schwa and the ultima does not

[kəˈri]	'small'	[qurəˈpus]	'cloud'
[cəˈvus]	'sugarcane'	[qapəˈdu]	'gall'
[kəˈman]	'to eat'	[kəməˈlaŋ]	'to know'

(c) Stress the final syllable if both penultimate and final syllables contain schwa

[ɭəˈʎət]	'lip'	[ʎisəˈqəs]	'nit'
[tsəˈməɭ]	'grass'	[masəŋˈsəŋ]	'to make something'

In Kenstowicz (1997) and de Lacy (2002a, 2006)'s theories, Piuma Paiwan's stress system would be analyzed using a constraint such as $*\text{HD}_{\text{Foot}}/\text{ə}$ (or $*\Delta_{\text{Ft}}\leq\text{ə}$). Such a constraint imposes a direct requirement that foot heads not have the sonority of schwa (or lower).

However, an alternative is presented by 'defective schwa' and 'minor syllable' theories – i.e. stress avoids schwa because schwa heads a prosodically defective syllable. Following Shih (2018b), we suggest that schwas in Piuma Paiwan are pressured to be non-moraic: i.e. they form a minor syllable. So, stress falls on the final syllable in [kərí] because the schwa is non-moraic (symbolized as [ᵊ] here – e.g. [kᵊrí]), and the head syllable of a foot must contain at least one mora.

While minor syllable theory allows an alternative to the direct sonority-foot reference theories of K97 and deL, we believe minor syllable theory provides a number of analytical and empirical advantages, and these advantages are particularly clear in this case.

Importantly, Shih (2018b)'s experiment and acoustic analysis confirm the basic claims about the position of stress by the impressionistic descriptions. F0 is a key diagnostic, as shown in Figures 3 and 4. For words with putative penultimate stress, F0 peaks over the penult (Figure 3); for words with putative final stress, F0 peaks over the final syllable (Figure 4). Thus, if F0 is a reliable indicator of foot head position, the experimental results support the impressionistic description.

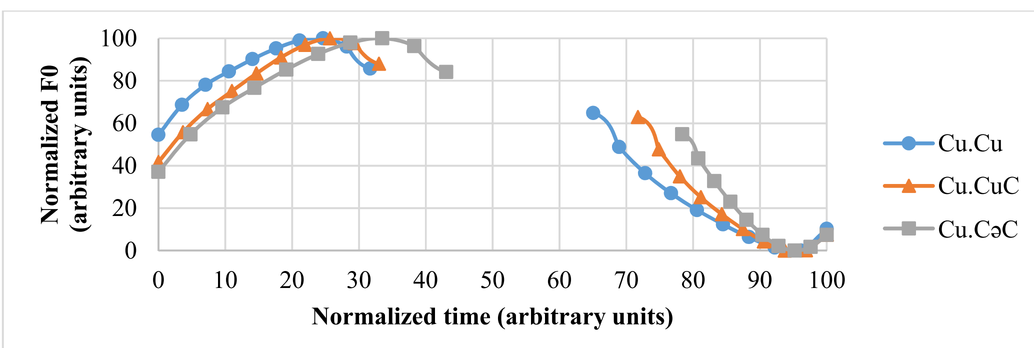

Figure 3. F0 over putatively penultimate-stressed words

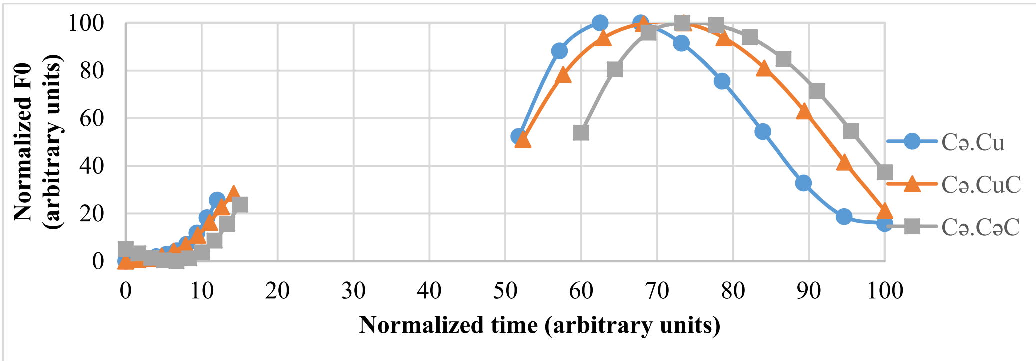

Figure 4. F0 over putatively final-stressed words

However, Shih (2018b) shows that previous impressionistic descriptions missed important generalizations about the duration of vowels in various stress environments. In words with the shape [CəˈCV] (where V is not schwa), the final vowel is long and the schwa is remarkably short: i.e. phonologically [C^{ə}ˈCVː^{μμ}] (we include moras here to be explicit). On average, [u]s in this environment were 214ms (s.d.=25ms) in duration in focused position (of peripheral vowels, only [u] was measured), compared to the much shorter stressed [u]s in [ˈCuCu] (mean=141ms; s.d.=31ms), and unstressed final [u]s (mean=156ms; s.d.=31ms).

Shih (2018b)'s analysis is that Piuma Paiwan feet must contain a minimum of two moras and be right-aligned, but schwas seek to be moraless (i.e. appear in a minor syllable). Consequently, underlying /CəCV/ must undergo two changes: one is that the schwa must lose its mora, and the second is that the V must become bimoraic – i.e. long. The output is then [C^{ə}(ˈCVː^{μμ})], with a penultimate non-moraic syllable and a final bimoraic syllable. The consequence of this form is that Piuma Paiwan actually involves a metrical system with a right-aligned quantity-sensitive trochee. There is no need to invoke any direct prohibition on having schwa as a foot head. Instead, the position of the foot head is a side-effect of schwa's desire to appear in a minor syllable. For Shih (2018b) this 'desire' is effected by the constraint *μ/ə "Incur a violation for every schwa that bears a mora"; this constraint is a specific instantiation of long-standing theories that regulate the sonority of syllable nuclei (e.g. Zec 2007, Prince & Smolensky 2004).

S18's theory makes a variety of additional predictions.

For CVCV words like [ˈvuvu], the need for a right-aligned bimoraic foot results in the phonological form [(ˈvu^{μ}.vu^{μ})], with two monomoraic vowels. (There is no motivation for a form such as *[vu$^{\mu}$(ˈvuː$^{\mu\mu}$)] to emerge as this would require either unfaithfulness to underlying mono-moraicity, or the appearance of long vowels, which are generally avoided). The duration results bear this prediction out, with both [u]s being significantly shorter than final stressed [u]s.

For CVCə words like [ˈtsukəs], the prediction is rather striking: that the output should have the form [(ˈCV$^{\mu}$.Cə$^{\mu}$)], with a mono-moraic schwa. Without a mono-moraic schwa, the foot would either lack two moras (*[(ˈCV$^{\mu}$.Cᵊ)]) or not be right-aligned (*[(ˈCV$^{\mu\mu}$)Cə]). This phonological analysis predicts that schwa in such words should have significantly longer duration than schwas in minor syllables. This is in fact S18's finding, with schwas predicted to be in minor syllables being around 50ms in duration (with around 20ms s.d.), while the schwa in CVCə words is significantly longer with a mean of 72ms (16ms s.d.).

Finally, the theory predicts that words with schwa in both penultimate and ultimate position necessarily involve a moraic schwa. In fact, the phonological form of words like [ɭəˈʎət] is actually [ɭᵊ(ˈʎəː$^{\mu\mu}$t)] – the first schwa has a very short duration (mean=50ms; s.d.=18ms), while the second is relatively very long (mean=134ms; s.d.=28ms) (c.f. monomoraic schwa at 72ms). Again, the phonological output [ɭᵊ(ˈʎəː$^{\mu\mu}$t)] contains a bimoraic right-aligned foot. S18 shows why the competing form *[(ɭə$^{\mu}$ˈʎə$^{\mu}$t)] loses in this competition.

The value of S18's theory is that it explains why vowels have different durations depending on their position, particularly for schwa. In contrast, theories such as K97 and deL's face difficulties in explaining cases like Piuma Paiwan because constraints against schwa in foot heads do not require schwas to be non-moraic. In fact, deL's theory does not even entertain the possibility of non-moraic schwas; after all, an underlying motivation of deL's theory is to avoid the idea that schwa can be *representationally* special – its specialness is *computational*, due to constraints that prohibit schwa in foot heads. So, two issues arise. If schwa is never representationally special (i.e. it always has at least one mora), then how does deL's theory account for the differences in duration between the three types of schwa in Piuma Paiwan? Recall that the schwas fall into three categories durationally: (a) ones with minimal (inherent) duration (means of around 40-50ms), (b) ones with duration comparable to short full vowels (means of 72-80ms), and (c) ones with duration comparable to long full vowels (means of 134-137ms). S18's theory accounts for these different types by moraic content: the ultra-short schwas are non-moraic, the middling duration ones have one mora, and the long vowels have two moras. However, if there are no non-moraic schwas – as deL's theory implies – then there is no way to explain the three durational types of schwa.

So, Piuma Paiwan seems to present strong evidence for three moraic types of schwa, thereby explaining both duration and stress position. A response would be to accept deL's theory, but admit degenerate syllables, such as mono-moraic schwa. The problem with such an approach is that it then undermines the need for constraints such as *HDFoot/ə: when stress avoids schwas, it could be due to the non-moraicity of schwa rather than because foot heads avoid low sonority vowels.

So, evidence for *HDFoot/ə would consist of a case where stress demonstrably avoided schwa, yet schwa had comparable duration to other vowels, or was otherwise demonstrably moraic. At this point, we are unaware of such evidence. Part of the problem is that determining which approach is correct requires careful analysis of vowel durations – both schwa's and other vowels' – in an appropriately controlled setting. Without such an analysis, reports are merely impressionistic, and as we have seen for Piuma Paiwan, impressionistic descriptions may correctly identify the location of stress (or at least, of pitch peaks) but miss duration differences entirely.

There are three other relevant experimental studies involving sonority-driven stress and schwa that we are aware of. Haghverdi (2016)'s analysis of Eastern Armenian was mentioned above. In it, stress landed on a final schwa. In S18's terms, this implies that final schwa is moraic, otherwise it could not serve as the head of a foot. Interestingly, Gordon et al. (2012) found that the mean duration of Armenian schwa was equivalent to that of high vowels ([i]=64ms (13ms s.d.); [u]=68ms (15ms s.d.); [ə]=68ms (26ms s.d.)), implying that they bear a mora, as expected under Shih (2018)'s theory.

Dobrovolsky (1999) reports the results of an acoustic analysis of Chuvash, which is reported to have final stress (e.g. [sar.la.ká] 'widely'), with retraction away from schwas (e.g. [jə.nér.tʃək] 'saddle'), and initial stress on words with only schwas (e.g. [tə́.tə.mər] 'we got up'). D541 reports that "R[educed] vowels that precede or follow a stressed syllable are in general extremely short and non-prominent" – just as one would expect if they were non-moraic. An interesting result is that in words with only reduced vowels there seems to be no acoustic measure that marks stress. In this case, then, schwas seem to be non-moraic in all situations, even to the point where there is no foot at all in words with only schwas.

The final case we know of is Blum (2018)'s analysis of Munster Irish, covered in the next section.

• *Munster Irish and allophony-driven footing*

Blum (2018) discusses a case of apparent sonority-driven stress in Munster Irish. There have been several impressionistic descriptions of Munster Irish stress (Ó Cuív 1944, Ó Sé 1989, 2008, Blankenhorn 1981, Gussman 2002, Hickey 2011, 2014), and they generally converge on the following generalizations, with some slight variations (Blum 2018§2.1). Note that MI also has vowel reduction, where every unstressed short vowel becomes schwa.

(11) *Munster Irish stress (data adapted from Gussman 2002)*

(a) Stress the leftmost long vowel or diphthong

[gaˈdiː] *gadaí* 'thief', [məˈkaːntə] 'modest', [əməˈdaːn] *amadán* 'fool'

(b) Else stress the second syllable if it contains an [a] followed by a [x]

[bəˈkax] *bacach* 'lame', [kəˈdʲaxtə] *cuideachta* 'company'

(c) Else stress the initial syllable

[ˈsoləs] *solas* 'light', [ˈokəɹəx] *ocrach* 'hungry'

On its face, Munster Irish seems like at least a partial sonority-driven stress system. The sonority-driven aspect involves [ax] where the [a] is in the second syllable: e.g. [bə.ˈkax] 'lame', *[ˈba.kəx]. However, [ax] later in the word does not attract stress (e.g. /okərax/ → [ˈokəɹəx], *[əkə.ˈɹax]). Also, long vowels attract stress over [ax] (e.g. /ʃeːʃax/ → [ˈʃeːʃəx] 'melodic', *[ʃeːˈʃax]). A curious aspect of the system is that the [x] does not appear to necessarily belong to the second syllable: e.g. [bə.ˈka.xə] 'lame (pl.)' (Green 1996:4).

However, Blum (2018) (B18), which involved a production experiment and acoustic analysis, made an additional significant discovery: "The [a] in Cax syllables does not reduce in any unstressed position: neither in CaxˈCVː, nor in ˈCaxCax" (p.20). In other words, [x] blocks /a/ from becoming schwa in all unstressed positions.

B18's analytical proposal is that MI stress is driven by allophony. Unstressed short vowels seek to reduce, and the metrical system requires a trochaic foot at the left edge. In most words, these two requirements can be met: e.g. /faɹaga/ → [(ˈfa.ɹə)gə]. However, in words with the shape /CVCax/, like [bəˈkax], it is not possible to meet both requirements. One option is to stress the leftmost syllable and not reduce the /a/ (e.g. /bakax/ → [ˈba.kax] – recall that /a/ cannot reduce before [x]). The other option is to stress the second syllable and reduce the first vowel (e.g. [bəˈkax]). B18's analysis is that in the face of this conundrum, MI opts for the latter approach: stress moves to the peninitial syllable so that at least one short vowel can reduce.

B18's analytical insight can be coupled with Shih (2018b)'s non-moraic schwa theory by analyzing vowel reduction as mora loss. So, MI's stress system as requiring a left-aligned foot that is left-headed by default, but right-headed when the leftmost vowel can become non-moraic while the rightmost one cannot. This situation is formally expressed in tableau (12). Candidate (a) wins because it avoids reducing [a] before [x], and reduces unstressed syllables to non-moraic schwa (thanks to *NON-HEAD/μ "Incur a violation for every vowel that (a) is in the non-head syllable of a foot and (b) bears a mora"), albeit at the expense of not having a left-headed foot. Candidates (b), (c), and (e) all fail because they fatally violate *NON-HEAD/μ by having an unstressed moraic vowel in a foot. Candidate (d) avoids violating *NON-HEAD/μ, but at the cost of having a reduced vowel before an [x] – blocked in MI. In other words, as Blum (2018) observes, the pressure to reduce vowels forces feet to change shape. Importantly, there is no constraint here that relates sonority directly to foot structure. There is a constraint that relates schwa to segmental context – *əx, and one that relates foot structure to moraic content (*NON-HEAD/μ), but no constraint that bans a structure consisting of a prosodic element and a sonority category (e.g. *NON-HEAD/ə).

(12) *Munster Irish stress movement due to allophony, adapting Blum (2018)*

	/bakax/	*əx	*NON-HEAD/μ	IDENT-F	TROCHEE
☞	(a) ($b^{ə}$.ˈ$ka^{μ}x$)			*	*
	(b) ($ba^{μ}$.ˈ$ka^{μ}x$)		*!		*
	(c) (ˈ$ba^{μ}$.$ka^{μ}x$)		*!		
	(d) (ˈ$ba^{μ}$.$k^{ə}x$)	*!		*	
	(e) (ˈ$bə^{μ}$.$ka^{μ}x$)		*!	*	

Finally, [CaxCax] words (e.g. [ˈlʲax.tax] *leachtach* 'liquid') have stress on the initial syllable but reduce neither [a]; this is due to *əx outranking *NON-HEAD/μ, as seen in tableau (13).

(13) *Munster Irish stress movement due to allophony #2*

	/lʲaxtax/	*əx	*NON-HEAD/μ	IDENT-F	TROCHEE
☞	(a) (ˈlʲaμx.taμx)		*		
	(b) (ˈlʲaμx.tᵊx)	*!		*	
	(c) (lʲᵊx.ˈtaμx)	*!		*	*
	(d) (lʲaμx.ˈtaμx)		*		*!

In conclusion, the apparent sonority-driven stress of Munster Irish can be ascribed to the need to block reduction of /a/ before [x], and no constraints that directly relate sonority to foot heads (or non-heads) are necessary. In general terms, restrictions on allophony can influence footing, and so appear to be sonority-driven stress.

4. Implications

We have argued above that there is no robust evidence for a phonological mechanism that induces a deviation from default foot form because of a direct condition on the sonority content of a foot – i.e. 'sonority-driven stress'. However, *apparent* stress avoidance of low-sonority vowels is possible when it is due to the incidental effect of other phonological conditions. When schwa is required to be moraless, foot conditions on moraic content may cause deviation from default footing, as in Piuma Paiwan. When conditions on allophony override foot restrictions, feet may also depart from their usual position, as in Munster Irish.

Our argument in section 3.1 might seem to be that impressionistic descriptions in general are unreliable. This is not necessarily the case. The reliability of <u>any</u> device and methodology must be examined with respect to a particular task; it is possible that humans are very reliable with some detection tasks (e.g. identifying forms of suppletive allomorphs). In this regard, we simply conclude here that *in regard to sonority-driven stress*, the impressionistic method is not reliable. One consequence is that future work on sonority-driven stress – and perhaps all stress – cannot be solely impressionistic or rely on impressionistic sources. For cases of putative sonority-driven stress in particular, it is necessary to detect fine distinctions in duration and examine acoustic properties (e.g. intensity, spectral tilt, F1/F2) to a degree that is beyond the capacity of humans unaided by appropriate hardware and machine analysis.

However, we again emphasize that *any* device and methodology must be examined for reliability. This point also applies to experiments – whether production or perception, and however analyzed; it is not adequate to assume that any device – including microphones, digitizers (e.g. sound cards), palatographs, spectrographs, or analytical software – is reliable. To emphasize this point, conducting experiments is in no way an immediate panacea for methodological reliability: we are actually not advocating for acoustic experiments – or any other non-impressionistic methodology. We are instead advocating that *any method* used to gather evidence must be evaluated for reliability. For example, above, we determined that the method of relying on impressionistic descriptions is not reliable; all other methods require the same determination to be made.

We are aware that our article has implications beyond sonority-driven stress. For metrical theory, the only potential influence on feet apart from edges is moraic content (and perhaps tone – de Lacy 2002b, 2007, though cf. Oakden 2018; also see de Lacy 2007 for other structural factors). The finding in this article means that metrical stress theories can be more restrictive, eliminating mechanisms that allowed poorly constrained reference to non-moraic properties, as in H&V and H95 (see section 2 above).

Perhaps the broadest issue that we broach here is the question of "what is good evidence?" This question has rarely been addressed in theoretical phonology (though see de Lacy 2008, de Lacy & Kingston 2013 for relevant discussion). Even so, we have identified one major requirement here, widely accepted in other fields: methods must be provably reliable for them to have value in producing evidence (e.g. Ray 2009).

Furthermore, sonority-driven stress is not obviously a special case in phonology. We suspect that the same discoveries about reliability of impressionistic descriptions – and even experimental work – could be made for other areas, too. It is possible that what we have uncovered for sonority-driven stress evidence indicates a broader crisis within phonology, and perhaps in other linguistics fields: i.e. that the reliability of evidentiary methods is largely unknown, and so the evidence arising from those methods is of indeterminate value. Without adequate evidence, the success of phonological theories cannot be tested. It seems to us reasonable to consider a science without testable theories to be in a state of crisis.

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