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Sensitivity to complex onsets in Iron Ossetian

Amber Lubera*

[a]University of Arizona – allubera@arizona.edu

This paper describes and analyzes the onset-sensitive stress system of Iron Ossetian (Eastern Iranian; Russia, Georgia; henceforth Iron). Iron instantiates a rare stress pattern that has been controversially identified in previous literature. Attested onset sensitive systems are commonly sensitive to onset presence or quality (Hyde 2007; Gordon 2005; Topintzi 2010). However, stress in Iron is categorically sensitive to onset complexity, but not onset presence. Syllables with simplex onsets or null onsets are light. Those with complex onsets are heavy. Such a pattern has only been claimed for a few languages, often controversially (Topintzi 2010, 2022). This pattern provides a challenge for current OT frameworks designed to analyze onset sensitive stress. This paper first establishes evidence for the weight of the aforementioned syllable types and then provides an OT analysis for this onset sensitive pattern.

Keywords: onset-sensitive stress; Iranian linguistics; phonology; Optimality Theory

1 Introduction

Onset sensitivity in world languages is uncommon, but not unheard of. At least 17 languages have been described as having some kind of onset sensitivity, including Alywarra, Arrernte, Banawá, Bislama, English, Russian, Iowa-Oto, Júma, Lamalama, Manam, Mbabaram, Nankina, Pirahã, Dutch, Arabela, and Tümpisa Shoshone (Gordon 2005; Topintzi 2010; Hyde 2007; Ryan 2014; Everett & Everett 1984; Buller, Buller & Everett 1993; Goedemans 1998; Gordon 2006). Most onset sensitive systems are sensitive to the presence of an onset, the quality of an onset, or a combination of both (Topintzi 2010; Gordon 2005). Cross-linguistically, sensitivity to onset presence is more common in onset sensitive systems than sensitivity to onset quality (Gordon 2005). Additionally, systems that show onset sensitivity also show sensitivity to properties of the rime (either the nucleus or coda) (Gordon 2005, 2006). Essentially, onset sensitive systems also generally consider vowel quality or coda presence, both of which take precedence over onset sensitivity when assigning stress. Finally, in systems where onset quality matters, onset segments with lower sonority are frequently heavier than those with higher sonority. Less sonorous onsets will be stressed over more sonorous onsets (e.g. Tümpisaa Shoshone, Alyawarra), potentially due to the perceptual benefits that a low sonority consonant may provide for following vowels (Gordon 2005) or because of their greater effect on syllable *p-center* (Ryan 2014). However, Iron's stress system does not fit into these categories. Data in this paper shows that stress in Iron is categorically sensitive to the complexity of the onset, but not presence or

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quality of the onset. While this pattern does follow the generalization of rimal primacy (i.e. vowel type is most important), a syllable with either a null onset (0 consonants) or a simple onset (1 consonant) are both considered light, while a syllable with a complex onset (2 consonants) is heavy. In addition, codas play no role in stress assignment.

Onset complexity, on a gradient basis, has been previously tied to stress assignment. Ryan (2014) convincingly shows that onset complexity in English is significantly correlated with stress occurrence in both corpus and experimental data. Russian also shows this tendency in corpus data (Ryan 2014). These onset tendencies have a weaker effect than rimal considerations, in line with the typological predictions (Gordon 2005; Ryan 2014). Additionally, Ryan (2014) finds consistent evidence that each additional consonant in the onset affects weight (i.e. V < CV < CCV is significant). This is considered a gradient effect on the *p-center* of a syllable, rather than defining a binary categorization for weight based on complexity (Ryan 2014). In other words, it is not the case that any particular syllable type is defined as heavy or light based on the onset structure. Rather, it is a statistically significant trend that a syllable with more consonants in the onset is more likely to be stressed. Iron, on the other hand, appears to be categorical in nature, defining heavy and light syllables for stress assignment. Additionally, it is not additive or gradient, since a simplex onset (CV) does not outrank a null onset (V) which indicates a single consonant in an onset has no effect on stress.

Some sources have discussed languages which appear to have similar categorical onset complexity systems for stress assignment, but the data is not conclusive. For instance, Camden (1977) describes Bislama as a language in which syllable weight is determined by onset complexity and coda presence. Syllables with a coda are heavier than those without and syllables with complex onsets are heavier than those with simplex onsets, but coda presence takes precedence in stress assignment (CCVC > CVC > CCV > CV) (Camden 1977; Gordon 2005).[1] However, Topintzi (2010) argues that this system has been misanalyzed and does not provide evidence for a system in which complex onsets contribute weight. Topintzi (2010, 2006) argues that the syllabification presented in Camden (1977) is questionable and examples are restricted to abstract forms. Topintzi (2010) also states that the analyses of Gordon (2005) and Camden (1977) result in divergent stress predictions. Finally, Crowley (2004) presents evidence that stress can be frequently determined by the origin of the word and presents example words with stress that contradicts both Gordon (2005) and Camden (1977). Topintzi (2010) argues that the lack of consensus makes this language a poor example of a system where onset complexity plays a role in stress. Gordon (2005) also lists Nankina as a language in which complex onsets are heavier than simplex onsets and no onset, but that there is no difference between simplex onsets and no onset (CCV > CV, V). Topintzi (2010) argues that this is a faulty analysis because Nankina lacks true CCV syllables. The work by Spaulding & Spaulding (1994) states that word-initial clusters are split by epenthetic vowels. Complex onsets do sometimes occur, but as a byproduct of the phonetic realization of this epenthetic vowel (Topintzi 2010). Additionally, some apparent complex onsets can be described as complex single segments with secondary articulation such as affricates, pre-nasalized segments, and consonant-onglide sequences (Topintzi 2010). Therefore, Nankina can be described as a system in which onset presence is relevant to stress assignment, but not complexity.

Topintzi (2010) furthermore argues that a system in which complex onsets are heavy while a simplex onset and lack of onset are equivalent (CCV > CV, V) should not occur if current constraints are utilized because they generate moraic onsets and codas independently of onset or coda complexity. Moraic consonant constraints simply evaluate whether there are consonants in a particular position and assign moras. In other words, allowing a complex coda or onset to be moraic necessitates that a simplex onset or coda must also be moraic because they are in the same position. It is also possible that complex onsets can be heavier than simplex onsets (CCV > CV), but that requires simplex onsets to also be heavier than no onset (CV > V).

This paper does not intend to argue against this analysis for other languages. This hierarchical ranking is

[1] The original papers for both Camden (1977) and Spaulding & Spaulding (1994) are not accessible. The description here is taken from the work of Gordon (2005).

apparent in the aforementioned data by Ryan (2014). In addition, many sources describe Hindi as an example of additive moraic codas (VCC > VC > V). However, the additive moraic analysis is not consistent with the data in Iron. This paper provides evidence syllables with a complex onset are considered heavy, while syllables with a simplex onset or no onset are of equal weight (CCV > CV, V). Iron necessitates a new constraint to capture the behavior of languages that are categorically sensitive to onset complexity.

This paper first provides a detailed description of Iron, including speaker population demographics (Section 2) and a summary of the sound system in Iron (Section 3). Next, previous stress analyses are detailed and evaluated (Section 4). Evidence for onset sensitivity and syllable weight by type is then presented through analysis of infinitive verbs, plural formation, and agentive nominalizations (Section 5). Since onset complexity is key to onset sensitivity, the following section examines the behavior of clusters in Iron (Section 6). Briefly, the cluster type containing the labial glide is also further evaluated (Section 7). Following this, Section 8 provides an OT analysis of Iron's stress system and word minimality constraints. Finally, Section 9 discusses the typological implications of this stress system.

2 Iron Ossetian

Ossetian (also called Ossetic) includes two dialects: Iron and Digor. While similar, they are not mutually intelligible (Erschler 2018, 2021). The work in this paper concerns only Iron Ossetian and makes no claims about Digor. Ossetian is generally considered to be a Northeastern Iranian language along with the related languages, Yaghnobi and Sogdian (Hettich 2002; Abaev 1964) and is spoken in the Republics of North Ossetia-Alania (Russia) and South Ossetia (Georgia; semi-autonomous) (Erschler 2018; Hettich 2002). Some unknown number of speakers additionally live in surrounding regions in Russia, Turkey, and Georgia. It is estimated there are at least half a million speakers of Ossetian (Iron & Digor) with Iron making up the majority (Erschler 2018; Hettich 2002; Erschler 2021). According to Nationalia, a news source dedicated to reporting on stateless people and language diversity, there are approximately 755,000 inhabitants in North and South Ossetia. Of those, 600,000 speak either Iron or Digor (Nationalia 2020). According to Erschler's (2018) translation of Kambolov (2007), no monolingual speakers remain in North Ossetia. In this region, Ossetian is restricted to private use while Russian is "the language of local authorities and courts" (Erschler 2018). The majority of grammar sketches for both dialects are written in Russian, but a handful have been translated, including Abaev (1964). Both Iron and Digor use a Cyrillic orthography which resembles (but is not identical to) Russian Cyrillic orthography.

The presented data was primarily collected through elicitation with an adult male speaker of Iron living in the United States as part of an NSF Grant to produce a comparative grammar of Iranian Languages. Elicitation sessions began in 2020 in person and transitioned online due to the COVID-19 pandemic. Elicitation was recorded using built-in recording features for online meetings and occasionally through a local high quality recorder used by the consultant. This ensured high quality audio for phonemic analysis when necessary. Over 100 hours of elicited speech was collected. While the majority of data comes from a single speaker, it was compared to online resources such as the Glosbe Ossetian-English dictionary (Glosbe 2021) and the Ossetic National Corpus (Belyaev & Vydrin 2021). Although these resources contain only the Cyrillic orthography, phoneme-grapheme correspondences described by Abaev (1964) and Erschler (2018) confirmed the elicited phonemic transcriptions and glosses. The lexical stress judgments presented in this paper were primarily determined through native speaker intuition and acoustic correlates. All words presented in this paper were collected in isolation[2] with at least 3 repetitions, commonly across different sessions. The

[2] Some, but not all, words were additionally elicited in larger phrases. When possible, the stress pattern of words collected in isolation was compared to the patterns in phrasal contexts. Cues for stress and stress assignment were consistent, but the location of stress sometimes varied. Lexical stress can be overwritten by phrasal stress during topicalization, which is frequent in Iron. In these cases, stress in phrases following the topicalized phrase was deleted. The most prominent word in a phrase receives stress consistent with the generalizations in this paper, and secondary stress on surrounding words did not occur. However, not all words were examined in both contexts, so no conclusions are drawn from phrasal data in this paper. All generalizations described herein

consultant had strong stress intuitions for these isolated words and was consistent when indicating stress, even across sessions. In addition, stressed syllables were consistently associated with vowel lengthening and higher pitch. Syllable breaks for the presented data were determined by adherence to Iron phonotactics and confirmed by the consultant. Due to the consultant's preference, word internal clusters were split between syllables rather than preferring a maximal onset.

3 Segmental phonology

This section presents the basics of segmental phonology of Iron, including consonant inventory, vowel inventory, syllable structure, and word minimality requirements.

3.1 Vowels

Iron features a 7 vowel system, presented in Table 1. This inventory aligns with those given by Erschler (2021), Hettich (2002), and Abaev (1964) with slight modifications. There is some disagreement regarding exact characteristics of the central vowels, which show great allophonic variation (Hettich 2002; Erschler 2018). Here, the central vowels are characterized as /ɨ ə/, following Hettich (2002). Other vowels, including /ɛ/ and /ɪ/, occur only in borrowed Russian words and are excluded. The sound /a/ is most often described as a central or back low vowel and is longer than other central vowels. The sound /o/ varies with /ɔ/.

Table 1: Vowel inventory of Iron Ossetian

	Front	Central	Back
High	i	ɨ	u
Mid	e	ə	o
Low		a	

All sources on Iron make a distinction between the strong vowels [i e a u o] and the weak vowels [ɨ ə] (Hettich 2002; Erschler 2018; Abaev 1964).[3] Weak vowels tend to reduce and delete, especially when adjacent to strong vowels. They also appear epenthetically to resolve phonotactic violations (Hettich 2002; Abaev 1964). In general, strong vowels are longer than weak vowels. The strong vowels /a/ and /o/ alternate with /ə/ in plural formation, past tense, and in compounds, but the reduced vowels behave identically to underlying /ə/ vowels. The status of diphthongs in the language is questionable. Sequences such as [oj] and [əw] do occur, but are analyzed as sequences of a vowel and glide (Hettich 2002; Abaev 1964).

3.2 Consonants

The consonant phoneme inventory is presented in Table 2. Iron is unique among Iranian languages for the presence of ejective stops and affricates. This is hypothesized to be an areal influence from the nearby Caucasian languages (Hettich 2002; Erschler 2018). Ejectives occur in borrowings from Caucasian languages, borrowings from Russian that have been present in the language for a long time,[4] physical action words, and onomatopoeic words (Hettich 2002) They are also present in words of Iranian origin and are easily found throughout the language (Hettich 2002). Voiceless stops are aspirated syllable initially and released syllable finally, which is indicated by the aspiration diacritic /ʰ/ in both contexts. However, voiceless stops are unaspirated in consonant clusters (e.g. [ʃtəɡ] 'bone' and [twaɡ] 'sour' vs. [tʰəχɨn] 'to fly') (Hettich 2002; Abaev 1964).

represent lexical patterns.

[3] Iron vowels perfectly fit the description of a *full* vs. *reduced* vowel system from Gordon (2006).

[4] It is not clear why borrowings from Russian might feature ejectives, but this was reported by Hettich (2002) and confirmed in our data. It may be related to differences in voicing cues between the languages, but there is not enough evidence to state this as fact. While interesting, the distribution of ejectives is outside the scope of this paper.

Table 2: Consonant inventory of Iron Ossetian

	Bilabial	Labiodental	Alveolar	Postalveolar	Velar	Uvular	Glottal
Stop	p^h b p’		t^h d t’		k^h g k’	q	(ʔ)
Fricative		f v	s z	ʃ ʒ	χ	ʁ	(h)
Affricate			ʦ (ʣ) ʦ’	ʧ ʤ ʧ’			
Nasal	m		n				
Lateral			l				
Trill			r				
Glide	w			j			

For the majority of Iron speakers (Hettich 2002) and our consultant, [ʣ] is consistently reduced to [z]. Similarly, [ʦ] is often reduced to [s]. The sound [r] is in free variation with [ɾ] and [ɹ] (Hettich 2002). There is some evidence that the postalveolar and alveolar fricatives are in fact one phoneme rather than two. Minimal pairs for [s]/[ʃ] and [z]/[ʒ] are rare. The only known example is [ʃʃad] ‘flour’ vs. [sad] ‘lake’, but this comparison is difficult because of the initial geminate in [ʃʃad]. The consultant could not think of any other minimal pairs for these segments. Notably, the phoneme inventories in Hettich (2002) and Erschler (2021) mark [s] and [z] as distinct from [ʃ] and [ʒ], but the phoneme inventory in Abaev (1964) does not. Additionally, the [s] and [ʃ] are represented by the same symbol in the orthographic system, making them hard to distinguish in dictionary entries. Similarly, [z] and [ʒ] share the same orthographic symbol. Finally, the alveolar fricatives are also rarer than the postalveolar fricatives by a wide margin. This paper will include both as separate phonemes, following the work of Hettich (2002) and Erschler (2021), but future analyses may find they are better described by the same phoneme.

The glottal sounds [h] and [ʔ] are rare and are often excluded from the phoneme inventory (Hettich 2002; Abaev 1964). The sound [h] only occurs in a few words such as [ho] ‘yes’ (which can variably be produced as [o], [wo], or [ʔo]). According to Erschler (2018), [ʔ] is sometimes inserted before word initial vowels, but this was not consistent with the collected data. It is possible that this generalization is drawn more frequently from data in Digor rather than Iron, or that it refers to a phrase initial position (i.e. ‘yes’ in phrase initial position has a glottal sound added). There is no word in which [ʔ] is consistently produced in our data. Additionally, in larger phrases, coerced multi-word VV sequences are resolved through glide insertion, deletion, or mergers based on the vowel type. Glides are most frequently inserted between two adjacent strong vowels, while two adjacent weak vowels often merge to form one strong vowel. A weak vowel that is adjacent to a strong vowel will delete.

Most consonants are palatalized before front vowels [i] and [e] (e.g. [d^{j}enʤɨʒ] ‘ocean’; [n^{j}eʃ^{j}i] ‘melon’). Palatalization of the velar stops [k^h g] often causes them to affricate to [ʧ ʤ] respectively. Iron also makes a distinction between plain and labialized consonants for the velar and uvular place of articulation. However, there is some debate on whether labialized consonants exist or if they are sequences of a consonant and labial glide [w] (Erschler 2021). In our data, both occur. Velar and uvular consonants are labialized before [ɨ] but consonant-glide sequences also exist and are allophonically distributed. A velar or uvular sound (e.g. [k^h k’ g q χ ʁ]) followed by an orthographic [wɨ] indicates a labialized consonant (e.g. [χ^{w}ɨ], [k’^{w}ɨ], [g^{w}ɨ], etc.). In all other cases, [w] is considered an independent segment. Labialized consonants are orthographically represented by two segments, but act as one for stress assignment (see Section 7).

Most consonants, except for ejectives, and the sounds [b], [v], [s] and [z], can occur as geminates in Iron. Geminates are orthographically represented by two identical letters. The status of geminates in Iron is questionable, and a full analysis of geminates should be undertaken in the future to better understand these segments. Several sources, including Hettich (2002), call these sequences clusters rather than geminates. In addition, our consultant described geminates as two copies of a segment.[5] They are often split and syllabified in both coda and onset position. Example words with geminates are provided in (1). Since they are often ambisyllabic, they have been represented by two identical segments. This list is by no means exhaustive.[6]

(1) Geminates in morphologically simple words

Intervocalic

Segment	*Singleton*	*Gloss*	*Geminate*	*Gloss*
p	ˈʃa.pʰon	‘soap’	ləp.ˈpu	‘boy’
w	ˈʃqi.wɨn	‘to fly out’	ləw.ˈwɨn	‘to stand’
t	ˈk’u.tʰu	‘barn’	bət.ˈtɨn	‘to tie’
d	ˈfi.dar	‘firm’	qʷɨd.ˈdag	‘business’
r	ˈʃu.rɨn	‘to chase’	pʰər.ˈrəʃt	‘flapping’
l	bə.ˈlaʃ	‘tree’	fəl.ˈla.jɨn	‘to get tired’
ʃ	ˈnʲe.ʃʲi	‘melon’	χəʃ.ˈʃɨn	‘to raise’
ʒ	ˈwa.ʒal	‘cold’	fəʒ.ˈʒəg	‘Fall/Autumn’
j	ˈwa.jɨn	‘to move/hit’	əj.ˈja.fɨn	‘to catch’
k	tʰə.ˈma.kʰo	‘tobacco’	tʰək.ˈkə	‘now’
g	ˈgo.gɨʒ	‘turkey’	mɨg.ˈgag	‘family name’
χ	ˈri.χʲi	‘mustache’	ʒəχ.ˈχon	‘earth’
q	ˈʃa.qa.daχ	‘island’	ˈqaq.qə.nɨn	‘to protect’

Word final

Segment	*Singleton*	*Gloss*	*Geminate*	*Gloss*
p	–	–	k’opp	‘box’
w	ˈaʃ.tʰəw	‘middle’	–	–
t	bɨ.ˈnatʰ	‘place’	χatt	‘time’
r	bɨ.ˈdɨr	‘pasture’	–	–
l	bal	‘cherry’	–	–
ʃ	fɨʃ	‘sheep’	χəʃʃ	‘carry’
j	moj	‘husband’	–	–
k	–	–	wə.ˈrɨkk	‘lamb’
χ	–	–	səχχ	‘salt’

Broadly, geminate voiceless stops are unaspirated and voiced geminate stops are devoiced, making them sound quite similar (Abaev 1964). For instance, the word for ‘family name’ [mɨg.gag] contains an intervocalic geminate /gg/ which sounds like [kk]. The same can be said of /dd/ which surfaces as [tt]. Geminates most often occur intervocalically, but can also occur word finally for voiceless stops and some fricatives. When intervocalic, they often follow weak vowels but not exclusively so, as in [qaqqənɨn] ‘to protect’. Notably, this is the only known example of [qq] and the only word with an intervocalic geminate following a strong vowel, which may indicate the segment [q] is somehow remarkable or that this word is atypical. Abaev (1964) notes that voiceless stops often appear as geminates word finally, which is confirmed in (1). Additionally, voiceless fricatives appear to geminate word finally. Geminates do not occur in monomorphemic consonant clusters in any position.

[5] The consultant described words like /k’opp/ with the sentence “The *puh* sounds kind of hard because there are two of them. There are two *puhs*.” This answer may be influenced by the orthography.

[6] Some categories in (1) are left blank. This indicates we do not have an example of this segment in this position in our data. It is possible that examples do exist, but were not collected during our elicitation.

Sources claim that [ʃ] and [ʒ] can appear as word initial geminates, but that initial geminates are extremely rare unless morphologically conditioned. Potential monomorphemic initial geminates like [ʃʃad] 'flour' and [ʒʒa.jɨn] 'to remain' were found in the Ossetic National Corpus (Belyaev & Vydrin 2021) but only one was confirmed during elicitation. The consultant indicated that 'to remain' is [ˈʒa.jɨn], with a singleton onset and the geminate only occurs when the prefix /ba-/ is added (e.g. [ˈbaʒ.ʒaj.ɨn]). The consultant also provided another example, /ʃʃə.ʒəm/ 'twentieth', but noted it was produced as [əʃ.ˈʃə.ʒəm]. Finally, the consultant confirmed that [ʃʃad] did feature an initial geminate, but it was not measurably longer than examples with an initial singleton [ʃ]. Thus, initial monomorphemic geminates are extremely rare and of questionable status in the language.

In summary, geminate segments occur intervocalically after a weak vowel in monomorphemic contexts. This pattern is extremely strong and only has one known exception ([qq]). In contrast, only voiceless stops and fricatives can geminate word finally, but this pattern is weaker. It may be the case that intervocalic geminates are environmentally conditioned (i.e. 'fake' geminates – see Hayes (1986) and Topintzi (2022) for discussion) while word final geminates may be lexically contrastive. However, as previously stated, more data needs to be collected. Derived gemination frequently occurs at morpheme boundaries, including with the affixation of case endings, preverbs, and past tense markers (Abaev 1964). For instance, when the plural morpheme [-tʰə] is affixed to a word that ends in a [t], [d], the final [t] or [d] combines with the suffix [-tʰə] to produce [-ttə]. When the plural suffix follows a sonorant (nasals, liquids, and glides), the [t] in the plural morpheme geminates, resulting in [-ttə] following the unchanged sonorant.

3.3 Syllable structure

In Iron, initial consonant clusters can contain no more than two consonants (Erschler 2018; Hettich 2002). Word final clusters most often contain two consonants, but can contain three consonants if the second consonant is either [ʃ] or [ʒ] (Hettich 2002). When possible, medial clusters prefer to split syllables, even when they form valid onset clusters (e.g. [ˈaʃ.tʰəw] 'middle'). There is a general dispreference for medial clusters, but they tend to form in the coda when they do occur.[7]

There are two valid types of initial clusters in Iron. The first type of cluster requires a postalveolar fricative in initial position (e.g. ʃC or ʒC).[8] In clusters with a postalveolar fricative in initial position, the second consonant is most often a stop, affricate, or nasal. Clusters tend to be homogeneous in terms of voicing, with the exception of [ʃm] and [ʃn]. Clusters without homogeneous voicing often show voicing assimilation in production. For example, /ˈʃga.rɨn/ 'to investigate' is always produced as [ˈʃka.rɨn] by the consultant.[9] Voicing assimilation also occurs at morpheme boundaries and in final consonant clusters. With the exception of the [ʒʁ], clusters containing two fricatives are not attested in morphologically simple words.[10] Some examples of postalveolar fricative clusters in morphologically simple words are given in (2). Many clusters that fit into the natural classes defined above are unattested in the data and in the online dictionary consulted (Glosbe 2021). For instance, Iron allows sequences of a postalveolar fricative and a stop or affricate, but sequences like [ʒb], [ʃt͡s], and [ʃt͡ʃ] do not occur in our data. Some clusters are attested, but only in recent borrowings, such as [ˈʃpɛk.tʰa.kʰəl] 'spectacle' and [ˈʃp'am] 'spam'.

[7] The author is unaware of any words where a complex onset occurs medially. The fact that onset clusters contribute weight for stress could be related to this general dispreference for medial onset clusters. It could be that there is a general dispreference for heavy syllables outside the available stress window, which encourages splitting consonants across syllables rather than allowing maximal onset.

[8] Clusters with an alveolar fricative in initial position (e.g. sC or zC) do occur more rarely. Words with [sw] and [zw] were found, but they are better examples of Cw clusters (discussed below).

[9] The consultant was also unable to think of an example with /ʃg/, indicating this was how it was spelled, not how it was said.

[10] Avoidance of two adjacent segments with the same manner of articulation (i.e. two fricatives) is relatively common typologically. It is possible that [ʒʁ] is allowed because of the high sonority of [ʁ] compared to other fricatives which differentiates their sonority and ability to identify the individual segments.

(2) Consonant clusters with initial postalveolar fricative

Cluster	*IPA*	*Gloss*
ʃn	ˈʃnɨv kʰə.nɨn	‘to paint’
ʃm	ˈʃmu.dɨn	‘to sniff’
ʃt	ˈʃtavd	‘thick’
ʃt’	ˈʃt’əlf	‘dot’
ʃʧ’	ˈʃʧ’il	‘crease’
ʃk	ˈʃkʷɨ	‘hindquarter (animal)’
ʃk’	ˈʃk’ə.rɨn	‘to drive’
ʃq	ˈʃqiʃ	‘splinter’
ʒm	ˈʒmə.lɨn	‘to move’
ʒd	ˈʒdɨ	‘lead’
ʒg	ˈʒgə	‘rust’
ʒn	ˈʒnag	‘enemy’
ʒʁ	ˈʒʁo.rɨn	‘to run’

The second valid type of initial cluster includes a consonant and labial glide in position 2 (Cw). Examples can be seen in (3). In these sequences, the initial consonant can never be a velar or uvular sound, since that results in a labialized consonant rather than a consonant cluster. The initial consonant in Cw sequences can be a nasal, fricative, or stop so long as they are not velar or uvular. These consonants can be voiced or voiceless. However, as before, not all examples in these natural classes are attested. For instance, sequences with [pw], [ʒw], or [mw] were not found in our data or consulted dictionaries (Glosbe 2021). Altogether, only clusters that conform to the format ʃC, ʒC, or Cw can occur word initially.

(3) Example words with Cw clusters

Cluster	*IPA*	*Gloss*
tw	ˈtwag	‘sour’
dw	ˈdwar	‘door’
bw	ˈbwar	‘skin’
ʃw	ˈʃwar	‘spring’
sw	ˈswan	‘hunt’
zw	ˈzwapp	‘answer’
nw	ˈnwa.ʒɨn	‘to drink’

Since Iron only allows two types of clusters, it could be called restrictive. However, the actual cluster types it allows are fairly common. According to many sources, including Henke, Kaisse & Wright (2012), Goad (2012), and Morelli (1999, 2003), the most common type of cluster typologically is a sibilant fricative and stop. While the theoretical explanation for this pattern varies[11] the fact that sibilant fricative clusters are typologically common is undeniable, which makes their presence in Iron unsurprising. How these may be handled structurally will be further discussed in Section 6.

As for the second type of cluster, glides and liquids are one of the most common sounds to occur in position C_2 crosslinguistically (Parker 2012). In fact, Maddieson (2013) in WALS (Chapter 12) separates languages by syllable structure complexity (between simple and moderately complex) on the basis of whether

[11] These types of clusters are notable for violating the Sonority Sequencing Principle (SSP). Many argue that clusters with a fricative+stop enjoy some special status in which they are not beholden to the SSP. Initial sibilant fricatives have been frequently analyzed as extrametrical, treated as appendices, syllabified in coda position, or otherwise separated out. Some researchers have rejected this assumption and instead proposed that perception-based explanations better account for typologically common clusters than SSP (Henke et al. 2012). The theoretical treatment of sibilant clusters will be discussed in Section 6.

they allow CC with a liquid or glide in position C_2. Thus, these clusters are a hallmark of moderately complex syllable structure. Languages that allow more complex syllable structures will always allow some type of cluster with glide or liquid in position C_2. While it may seem stipulative that Iron only allows clusters with glides (and not liquids), Parker (2012) shows that there is a typological division between languages that allow only glides in C_2 and those that allow only liquids in C_2 despite their similar status in sonority. Quite obviously, Iron would exemplify a language that allows glides, explaining the lack of examples in which high sonority liquids are present as C_2. Other languages, such as Angaataha and Pame, similarly only allow nasal-glide and obstruent-glide sequence but disallow glide-glide sequences, liquid-glide sequences, and all sequences in which a liquid is C_2 (Parker 2012). Incidentally, Pame also allows clusters with postalveolar fricatives in position C_1, which indicates the co-occurrence of these two types of clusters is not unheard of[12] (Berthiaume 2003). Therefore, the allowable consonant clusters in Iron are restricted to only two types, but those two types happen to be the most typologically common consonant cluster types.

3.4 Minimal words

According to Erschler (2018), minimal lexical words in Iron are CVC. Some words including pronouns and Wh-words can be CV or VC but are generally procliticized to a verb (Erschler 2018). These include [sɨ] ‘what’, [nə] ‘no’, [mə] ‘my’ and others which cliticize with nearby words. However, this generalization did not hold with the elicited data. Instead, it appears that minimal words are additionally sensitive to vowel type. Examples of minimal words with strong vowels (4) and weak vowels (5) are presented below.

(4) Minimal words with strong vowels

Structure	*Example*	*Gloss*
V	–	–
CV	tʰu	‘spit’
VC	ad	‘taste’
CCV	–	–
VCC	art	‘fire’
CVC	fatʰ	‘arrow’

(5) Minimal words with weak vowels

Structure	*Example*	*Gloss*
v	–	–
Cv	–	–
vC	–	–
CCv	ʒdɨ	‘lead’
vCC	ərχ	‘ravine’
CvC	bəχ	‘horse’

Words with a strong vowel minimally require a single consonant in either onset or coda position (CV_{STRONG} or $V_{\text{STRONG}}C$). “Words” that consist of only a strong vowel occur, but are restricted in use. For example, [aj] ‘this’ can be produced as [a] (e.g. [ˈa=ʃərd] ‘this summer’), but only when followed by a noun. The consultant described [aj] as “a word on its own” but stated [a] must be “next to something,” supporting an analysis in which it is a clitic or part of a larger prosodic word. The word surfaces as [aj] when used as the subject of a sentence (e.g. [ˈaj tʰəŋ.ˈg=u] ‘this is fun’).[13] Another example, [o] ‘yes’ is generally produced with epenthesis when it occurs in isolation (i.e. [wo], [ho], etc.). Since single vowel “words” can only occur when adjacent to other words, and not in isolation or as the subject of a sentence, it seems mostly likely that a single strong vowel is not acceptable as a minimal word.

Based on this evidence, this paper will assume that words with strong vowels must also have one consonant (CV_{STRONG} or $V_{\text{STRONG}}C$). Strong vowels can also occur with complex codas ($V_{\text{STRONG}}CC$) or with a simplex onset and coda ($CV_{\text{STRONG}}C$). As a note, we collected no words that contained only a complex onset and strong vowel (CCV_{STRONG}). There is no obvious reason why words of this form would be disallowed. Since both CV_{STRONG} (e.g. [tʰu]) and $CCV_{\text{STRONG}}C$ (e.g. [ʒnag]) can occur, the absence of CCV_{STRONG} appears to be an accidental gap rather than indicative of the requirements for minimal words. Words with a

[12] Pame and Iron Ossetian do have differences in allowable cluster sequences, but similarly disallow sequences with a liquid in position C_2 while allowing glides in position C_2. Pame is also notable for a number of sequences with secondary articulation characteristics (including labialization and palatalization) that are ambiguous. See Berthiaume (2003) for a full discussion.

[13] Notably this example also contains [u] (3.SG copula), which is cliticized.

weak vowel minimally require a coda and onset ($CV_{WEAK}C$), a complex onset (CCV_{WEAK}), or a complex coda ($V_{WEAK}CC$).[14] Onsetless and codaless syllables can and do occur frequently in longer words for both weak and strong vowels.

4 Previous generalizations about stress in Iron

All previous sources agree that Iron features a two-syllable stress window at the left edge of the word, with rare deviations (Abaev 1964; Hettich 2002; Hayes 1995; Kim 2003; Kager 2012). This is confirmed in our data. Stress consistently occurs within the first two syllables of words, with rare exceptions in loanwords (e.g. [ʧu.ma.ˈdan] ‘suitcase’ from Russian) and onomatopoeic words (e.g. [ʦɨr.ʦɨ.ˈrag] ‘locust’). Previous work claims that stress in Iron is solely determined by the quality of the vowel in the nucleus of the first syllable of a prosodic word (Abaev 1964; Hettich 2002; Erschler 2018). If the first syllable contains a strong vowel [a e i o u], stress falls on that syllable. When the first syllable contains a weak vowel [ɨ ə], stress falls on the second syllable. This predicts that stress will never occur on an initial syllable with a weak vowel.

Some examples from previous works were confirmed in our elicitation. All words with a strong vowel in the initial syllable (6) receive stress on the first syllable. Words with a weak vowel in the initial syllable (7) generally receive stress on the second syllable. Note that in this data, onsets and codas seem to play no role. Words with onsets do not behave differently from words without onsets. For instance, [ər.ˈtʰə] ‘three’ and [əm.ˈbal] ‘friend’ show the same pattern as [gə.ˈdɨ] ‘cat’ and [kʰər.ˈdo] ‘pear’. Additionally, [ˈa.fon] ‘epoch’ does not differ from [ˈdu.sɨn] ‘to milk’. In fact, even complex codas do not affect stress, as can be seen in the words [ləʁʒ.ˈgə.nəg] ‘polisher’ and [kʰəŋkʰ.ˈʃər] ‘dandruff head’. Neither example receives first syllable stress despite the presence of complex codas. Finally, [ˈar.gurd] ‘search’ receives first syllable stress despite a second syllable that has a strong vowel and complex coda.

(6) Strong vowel in initial syllable

Example	*Gloss*
ˈχar.bɨʒ	‘watermelon’
ˈfa.raʃt	‘nine’
ˈʧi.nɨg	‘book’
ˈgo.gɨʒ	‘turkey’
ˈqom.gəʃ	‘cowherd’
ˈnʲe.ʃʲi	‘melon’
ˈdu.sɨn	‘to milk’
ˈar.gurd	‘search’
ˈa.fon	‘epoch’
ˈa.χor.dan	‘place to study’

(7) Weak vowel in initial syllable

Example	*Gloss*
ər.ˈtʰə	‘three’
əm.ˈbal	‘friend’
gə.ˈdɨ	‘cat’
kʰər.ˈdo	‘pear’
qʷɨ.ˈmas	‘fabric’
pʰɨ.ˈrɨnz	‘rice’
ləʁʒ.ˈgə.nəg	‘polisher’
sə.ˈrɨn	‘to live’
kʰəŋk.ˈʃər	‘dandruff head’
bə.ˈrəg.bon	‘holiday’

While the generalization seems to hold for many words in Iron, the data in previous sources is often problematic. For instance, Hettich (2002) states that words with strong vowel in the initial syllable will be stressed (following the widely accepted generalization), but then presents words that do not follow this pattern including [pʰa.ˈpʰa] ‘daddy’, [ʃa.qa.ˈdaχ] ‘island’, and [ʃaj.ˈdaq] ‘quiver’. Additionally, some words with initial weak vowel syllables are marked for initial stress, like [ˈtʰək.kə] ‘now’. When elicited, our consultant provided stress judgments consistent with the generalization (e.g. [tʰək.ˈkə] and [ˈpʰa.pʰa] ‘daddy’) rather than the marked stress in Hettich (2002). Some forms in Hettich (2002) did mark words with initial weak vowels and complex onsets as having initial stress, including [ˈʃk’ə.fɨn] ‘to snatch’ and [ˈʃk’ə.rɨn] ‘to

[14] The word /χʷɨ/ ‘pig’ is the only known example of a CV_{WEAK} word. It is possible that this word somehow meets the minimality requirements discussed later in Section 8.4 due to the complex articulation on a fricative. As far as the author knows, this is the only example and is not indicative of a larger pattern.

rush' (pp 19). However, the mismatches between predicted stress and marked stress make the data unreliable. In Abaev (1964), stress is rarely marked. When it is, it is mostly consistent with the generalization above. Of course, the lack of data makes it difficult to fully confirm. While most works include a generalization of stress assignment, no known work focuses on stress assignment in Iron or explicitly discusses any relationship between initial consonant clusters and stress.

While works focusing solely on stress assignment are absent, many do make reference to the prosodic domain in Iron. Abaev (1964) argues that certain prosodic groupings are relevant for stress assignment, including complex predicates and other particles and clitics which are joined in an "accentual relationship to the preceding or following word" (pp 11). Some apparent shifts in stress can be explained by relying on the notion of the prosodic word as the domain for stress assignment. A prosodic word is an expression that contains multiple lexical words that act as a single prosodic unit. This means they behave like a single word for the purposes of stress assignment and satisfying word minimality. The notion of prosodic words in Iron is especially useful to understand the stress assignment of complex predicates (verbs with a light verb and non-verbal element) and words with prefixal clitics (Hettich 2002; Abaev 1964). For instance, compare the stress patterns of the words presented below, in which the light verb [kʰə.ˈnɨn] 'to do, to make' shows expected second syllable stress (8a), unexpected first syllable stress (8b & 8c) or missing stress (8d).

(8) Stress in complex predicates

a.	b.	c.	d.
/kʰə.ˈnɨn/	/lɨɡ ˈkʰə.nɨn/	/wəj ˈkʰə.nɨn/	/ˈtʰaʁd kʰə.nɨn/
kʰən-ɨn	lɨɡ kʰən-ɨn	wəj kʰən-ɨn	tʰaʁd kʰən-ɨn
do-INF	cut do-INF	sale do-INF	quick do-INF
'to make/do'	'to cut'	'to sell'	'to rush'

The differences in stress assignment are easy to explain when complex predicates are considered a single unit for the purposes of stress assignment. In that case, stress assignment follows the previously stated generalizations. If the first syllable of the complex predicate contains a strong vowel, it is stressed and no secondary stress occurs in the word (8d). If the first syllable contains a weak vowel, the second syllable of the complex predicate [ˈkʰə] is stressed (8b & 8c). Thus, considering prosodic words as the domain for stress assignment easily explains many divergent stress patterns.

5 Evidence of onset sensitivity in Iron

In contrast to previous generalizations in the literature, initial syllables with weak nuclei *can* bear stress when the onset of the initial syllable is complex (contains more than one consonant). Evidence for this comes from disyllabic words with monomorphemic onset clusters and productive morphological processes like pluralization and agentive nominalizations.

5.1 Infinitive verbs

Infinitive verbs contain the /-ɨn/ suffix, causing them to be minimally disyllabic. Therefore, verb roots with simplex and complex onsets can be easily compared. Words in (9) contain a weak vowel and simplex onset in the initial syllable. In these words, stress falls on the second syllable, as predicted. However, the verbs in (10) bear stress on the first syllable despite the fact that the first syllable contains a weak vowel.[15] All forms in (10) are morphologically simple (i.e. none contain preverbs which will be discussed in Section 6). Of special note, consider the extremely similar forms [mə.ˈlɨn] 'to die' and [ˈʒmə.lɨn] 'to move'. These differ only in the presence of a complex onset, but have different stress assignment. Based on this data, it is clear that initial syllables with a weak vowel can receive stress if they also contain a complex onset.

[15] All known words that contain a complex onset and weak vowel exhibit first syllable stress.

(9) Verbs with simplex onsets

Example	*Gloss*
tʰə.ˈχɨn	‘to fly’
χə.ˈrɨn	‘to eat’
mə.ˈlɨn	‘to die’
bɨr.ˈʃɨn	‘to attack’
lə.ˈwɨn	‘to stand’
dɨ.ˈmɨn	‘to smoke’
bəχ.ˈʃɨn	‘to tolerate’

(10) Verbs with complex onsets

Example	*Gloss*
ˈʃk’ə.rɨn	‘to drive’
ˈʃk’ə.fɨn	‘to snatch’
ˈʒmə.lɨn	‘to move’
ˈʒʁə.lɨn	‘to have small pieces fall off’
ˈʒmən.tɨn	‘to agitate’
ˈʒdə.χɨn	‘to return’
ˈʒgə kʰə.nɨn	‘to rust’

5.2 Plurals

Additional evidence for the weight of complex onsets comes from plurals of nouns that have varying syllable structure. When pluralized, some forms show phonological changes including palatalization of [k g] to [ʧ ʤ] respectively, gemination of plural morpheme onset, reduction of [a] to [ə].[16], and epenthetic vowel insertion of [ɨ] Stress assignment occurs in the plural after all phonological changes and reductions occur, and is not sensitive to the vowels or structure of the singular word. In (11), words that have an initial syllable with a weak vowel and simplex onset bear stress on the second syllable. This is the case regardless of coda complexity, underlying form, or number of syllables in the pluralized word.

(11) Plural words with simplex onsets & weak vowels

Singular		*Plural*	*Gloss*
fɨd	⟶	fɨt.ˈtə	‘fathers’
bɨl	⟶	bɨl.ˈtʰə	‘lips’
bəχ	⟶	bəχ.ˈtʰə	‘horses’
ləg	⟶	ləg.ˈtʰə	‘men’
səʃt	⟶	səʃ.ˈtʰɨ.tʰə	‘eyes’
mɨʃt	⟶	mɨʃ.ˈtʰɨ.tʰə	‘mice’
ʒəŋg	⟶	ʒəŋg.ˈtʰə	‘legs’
kalm	⟶	kəl.ˈmɨ.tʰə	‘snakes’
maʁʒ	⟶	məʁʒ.ˈtʰə	‘brains’
əf.ˈʃɨ.mər	⟶	əf.ˈʃɨ.mər.tʰə	‘brothers’
pʰər.ˈrəʃt	⟶	pʰər.ˈrəʃ.tʰɨ.tʰə	‘flaps’
rəʃ.ˈtʰəg	⟶	rəʃ.ˈtʰə.ʤɨ.tʰə	‘times’
əl.ˈχɨnts’	⟶	əl.ˈχɨn.ʦ’ɨ.tʰə	‘knots’
bə.ˈlaʃ	⟶	bə.ˈləʃ.tʰə	‘trees’

In contrast, each word in (12) contains a monomorphemic complex onset and features initial stress in the plural despite the weak vowel in the first syllable. As previously seen in verbs, initial syllables with a weak vowel and complex onset can bear stress. Thus, heavy initial onset clusters are not limited to a particular word type.

[16] The reduction of strong vowels is further discussed in Section 8.5

(12) Plural words with complex onsets & weak vowels

Singular		*Plural*	*Gloss*
ʃkʷɨ	⟶	ˈʃkʷɨ.tʰə	‘hind quarters (animal)’
ʃtɨr	⟶	ˈʃtɨr.tʰə	‘the big ones (big-PL)’
ʃt’əlf	⟶	ˈʃt’əl.fɨ.tʰə	‘dots’
ʃt’ol	⟶	ˈʃt’əl.tʰə	‘tables’
ʃtəg	⟶	ˈʃʤɨ.tʰə	‘bones’
ʃtəm	⟶	ˈʃtəm.tʰə	‘few PL’
ʒgə	⟶	ˈʒgə.tʰə	‘rusts’
ʒnag	⟶	ˈʒnəg.tʰə	‘enemies’
dwar	⟶	ˈdwərt.tə	‘doors’
bwar	⟶	ˈbwərt.tə	‘skins’
swan	⟶	ˈswənt.tə	‘hunts’
zwar	⟶	ˈzwərt.tə	‘shrines/angels’
ʃwar	⟶	ˈʃwərt.tə	‘springs’

Notably, the stress patterns of plural nouns with complex onsets and weak initial vowels (12) resembles the pattern of plural nouns with strong initial vowels (13). Both receive first syllable stress.

(13) Plural words with strong vowels

Singular		*Plural*	*Gloss*
quʃ	⟶	ˈquʃ.tʰə	‘ears’
bon	⟶	ˈbon.tʰə	‘days’
ʃin	⟶	ˈʃin.tʰə	‘backs’
zug	⟶	ˈzug.tʰə	‘flocks’
arm	⟶	ˈarm.tʰə	‘hands’
bal	⟶	ˈbal.tʰə	‘cherries’
bʲel	⟶	ˈbʲel.tʰə	‘shovels’
moj	⟶	ˈmoj.tʰə	‘husbands/marriages’
noʃt	⟶	ˈnoʃ.tʰɨ.tʰə	‘alcoholic drinks’
ˈa.fon	⟶	ˈa.fon.tʰə	‘spans of time’
ˈbo.t’o	⟶	ˈbo.t’o.tʰə	‘beards’
ˈnʲe.ʃʲi	⟶	ˈnʲe.ʃʲi.tʰə	‘melons’

Thus, initial syllables with complex onsets and weak vowels receive stress and are heavier than syllables with simplex onsets and weak vowels. However, no data thus far has shown any comparison between syllables with a complex onset, but weak vowel, and syllables with a strong vowel. This comparison will be handled in Section 5.3.

5.3 Weight comparison: Complex onset vs. strong vowel

In the previous section, evidence showed that stress is sensitive to complex onsets in plurals and infinitives. In both, a complex onset in the first syllable will receive stress regardless of the quality of the vowel in that syllable. What is unclear is whether there is a weight difference between complex onsets and strong vowels.

Typically, rimal sources (nuclei and codas) are the primary weight source, which would predict that vowel type is more important than the presence of complex onsets (Gordon 2005, 2006). In line with this, no examples exist in which a word with an initial strong vowel does not receive stress on the initial syllable. This could be explained by one of two possibilities. Potentially, strong vowels and complex onsets may be hierarchically ranked (rimal primacy). Alternatively, strong vowels and complex onsets may be tied in weight, but the first heavy syllable in a word receives stress.

To further evaluate this, I turn to agentive nominalizations. Agentive nominalizations are created in Iron through suffixation of the morpheme /-ag/ on verb stems. This suffix indicates a person who does the action denoted in the verb habitually. When the agentive nominalizer is affixed to a verb stem that contains a simplex onset and weak vowel, stress occurs as expected. Examples are presented in (14). Since the initial syllable has neither a strong vowel nor complex onset, stress falls on the second syllable. This baseline shows that agentive suffixes can bear stress and do so using the stress patterns previously described.

(14) Agentive suffix with a simplex onset and weak vowel

Infinitive		*Agentive*	*Gloss*
t^{h}ə.ˈχɨn	⟶	t^{h}ə.ˈχag	‘one who flies habitually’
k^{h}ə.ˈwɨn	⟶	k^{h}ə.ˈwag	‘one who cries habitually (cry-baby)’
χə.ˈrɨn	⟶	χə.ˈrag	‘one who eats a lot’
lə.ˈwɨn	⟶	lə.ˈwag	‘one who stands habitually (server)’
t^{h}ər.ˈʃɨn	⟶	t^{h}ər.ˈʃag	‘one who gets scared easily’

When the agentive suffix is added to a verb with a strong vowel in the initial syllable such as in (15), stress is assigned to the initial syllable. This indicates that the agentive suffix does not draw stress by itself, as some preverbs do (see section 6). Instead, stress is assigned based on the characteristics of the initial syllable, as seen in the general stress pattern of the language.

(15) Agentive suffix on stems with a strong vowel

Infinitive		*Agentive*	*Gloss*
ˈk^{h}a.fɨn	⟶	ˈk^{h}a.fag	‘one who dances habitually’
ˈli.zɨn	⟶	ˈli.zag	‘one who flees habitually’
ˈdu.sɨn	⟶	ˈdu.sag	‘one who milks habitually’
ˈt͡si.rɨn	⟶	ˈt͡si.rag	‘one who sucks habitually (baby)’
ˈʒdu.χɨn	⟶	ˈʒdu.χag	‘one that habitually twists’

The examples in (14) and (15) indicate that the agentive suffix is not special with regard to stress. Therefore, it can be utilized to compare the primacy of complex onsets and strong vowels for stress assignment. If strong vowels take primacy, the agentive suffix would be stressed over an initial syllable with a complex onset. Conversely, if the initial syllable receives stress, there are two possible explanations. Either syllables with complex onsets and strong vowels are equally heavy (unranked) or the stress window only includes the first heavy syllable. In the former case, we may expect superheavy syllables would shift stress if allowed. In the latter case, the first heavy syllable in the word receives stress regardless of the composition of the rest of the word. In words with complex onsets and the agentive suffix (16), stress falls on the first syllable.

(16) Complex onsets and weak vowel

Infinitive		*Agentive*	*Gloss*
ˈʃk’ə.rɨn	⟶	ˈʃk’ə.rag	‘one who drives a lot’
ˈʃk’ə.fɨn	⟶	ˈʃk’ə.fag	‘one who snatches habitually’
ˈʒmə.lɨn	⟶	ˈʒmə.lag	‘one who moves a lot’
ˈʒdə.χɨn	⟶	ˈʒdə.χag	‘one who returns habitually’
ˈʒmən.t^{h}ɨn	⟶	ˈʒmən.t^{h}ag	‘one who agitates habitually’

Since syllables with an initial cluster and weak vowel are stressed in (16), they must count as heavy for the purposes of stress assignment. There is no clear evidence that a syllable with a strong vowel will be heavier than a syllable with a weak vowel and complex onset. Both are stressed when they occur in the first syllable.

Notably, there is no apparent evidence for superheavy syllables in Iron. However, the phonotactics in Iron also actively restrict the ability of superheavy syllables to play an obvious role in stress. A superheavy syllable would require a strong vowel and onset cluster. In word initial position, this can and does occur frequently (e.g. /ˈʒdu.χɨn/ 'to twist'). However, since a heavy initial syllable is already stressed, there would be no predicted difference in behavior between a superheavy initial syllable and heavy initial syllable.

A superheavy syllable anywhere else in a word would also be predicted to draw stress away from the first syllable. However, Iron does not provide an opportunity for superheavy syllables to occur in later syllables because word medial clusters are syllabified across syllable boundaries (e.g. /mɨʃ.tʰɨ.tʰə/ 'mice'). When absolutely necessary, clusters will form in coda position rather than onset (e.g. /ləʁʒ.ˈgə.nəg/ 'polisher'). Therefore, a syllable in any position other than initial can contain a strong vowel but never a complex onset, allowing them to be heavy, but never superheavy. This rejection of onset clusters in medial position is likely related to the avoidance of superheavy syllables. Iron clearly prefers left edge stress. By avoiding superheavy syllables word medially, drifting stress is avoided.

The evidence presented here suggests a very simple stress generalization. Stress in Iron falls within the first two syllables of the left edge of a prosodic word. If the first syllable fulfills the requirements to be stressed (is heavy by containing a strong vowel or complex onset) it will be stressed. Stress is never drawn away from a word-initial heavy syllable. If the initial syllable is not heavy, stress falls on the second syllable.

6 Evidence for onset clusters in syllable structure

The previous section shows that complex onsets contribute to weight for the purposes of stress assignment. Recall that this pattern has been argued for other languages, but that previous analyses were criticized on the basis of whether onset clusters could be considered real consonant clusters. For instance, Topintzi (2010) argues that onset clusters in Nankina cannot contribute to syllable weight because onset clusters in Nankina are actually split by an epenthetic vowel and do not act as real clusters (c.f. description of Nankina in Section 1). Therefore, without definitive evidence of onset clusters in Iron, any onset sensitivity discussion is moot. In this section, the status of monomorphemic onset clusters in Iron will be evaluated by comparing their behavior to the behavior of consonant clusters that are derived through preverb affixation. This comparison provides evidence that monomorphemic clusters in Iron are true onset clusters and that the previous observations regarding the stress properties of words with monomorphemic clusters are valid.

Iron features several preverbs that play morphological roles, including focusing attention or adding grammatical information (Thordarson 2011). Some preverbs include the perfective marker /ba-/, the directional /a-/, atelic /fə-/, and others (Hettich 2002; Thordarson 2011; Abaev 1964). The most useful preverb for the stated purpose is /ʃ-/. This preverb is used to indicate either an upward direction (DIR), perfect aspect (PERF), or as an emphatic (EMPH). Although it is not the only preverb in Iron, it is the only one that does not contain a vowel. Therefore, when affixed, it creates morphologically derived clusters that can be compared to monomorphemic consonant clusters.

It is common for preverbs in Iron (and Iranian languages generally c.f. Balochi, Persian, etc.) to draw stress regardless of other stress characteristics of the language.[17] This is the case for the preverb /ʃ-/. Despite the general stress patterns in the language, the syllable that bears this preverb will always be stressed. For instance, consider examples (17a) and (17b) below. Both words have a weak vowel and either no onset (e.g.

[17] While the effects of preverbs on stress has been noted in numerous grammars for Iranian languages, the author is unaware of any work providing an analysis of these preverbs or any which argue for a phrasal versus lexical analysis. Further study is needed in this area. However, as the focus of this section is not the stress characteristics of the preverb, it is beyond the scope of this paper.

[ə.ˈvə.rɨn] ‘to put’) or a single onset (e.g. [sə.ˈrɨn] ‘to live’). Therefore, both words receive second syllable stress. However, when the preverb /ʃ-/ is affixed, the word [ˈʃə.vər.ɨn] ‘to put on top’ (17c) features first syllable stress.

(17)	a.	[sə.ˈrɨn]	b.	[ə.ˈvə.rɨn]	c.	[ˈʃə.vər.ɨn]
		sər -ɨn		əvər-ɨn		ʃ-əvər-ɨn
		live-INF		put-INF		DIR.up-put-INF
		‘to live’		‘to put’		‘to put on top’

The preverb can also occur medially in compound verbs like [swa.ˈnɨʃ sə.ˈwɨn] ‘to go on a hunt’ (18b).[18] The preverb affixes to the beginning of the verb [sə.ˈwɨn], but then resyllabifies in coda position for the preceding genitive noun [ˈswa.nɨ] (18b). Stress again falls on the syllable containing the preverb, even though it is in coda position. Another example of this is given in (18c) and (18d). Thus, assigning stress on the preverb takes precedence over any other stress characteristics, generalizations, or rules in the language. In other words, no claims about stress can be made by examining words that contain a preverb. However, comparing monomorphemic clusters to clusters derived through preverb affixation yields interesting comparisons that provide insight into the structure of monomorphemic clusters.

(18)	a.	[ˈswa.nɨ sə.ˈwɨn]	c.	[ˈzwəp.pɨ.t^{h}ə dət.ˈtɨn]
		swan-ɨ səwɨn		zwəpp-ɨt^{h}ə dətt-ɨn
		hunt-GEN to.go		answer-PL to.give-INF
		‘to go on a hunt’		‘to give answers’
	b.	[swa.ˈnɨʃ sə.ˈwɨn]	d.	[zwəp.pɨ.ˈt^{h}əʃ dət.ˈtɨn]
		swan-ɨ ʃ-sə.w-ɨn		zwəpp-ɨt^{h}ə ʃ-dətt-ɨn
		hunt-GEN PERF-to.go-INF		answer-PL PERF-to.give-INF
		‘to go on a hunt PERF’		’to give answers PERF’

When the preverb /ʃ-/ is added to a stem that has a simplex onset, it creates a cluster, as seen in the words presented in (19). Recall that monomorphemic clusters have many phonotactic restrictions (Section 3.3). For instance, postalveolar fricative clusters (ʃC and ʒC) require the second consonant to be a nasal or a homogeneously voiced stop or fricative. Monomorphemic clusters never contain two fricatives, excepting [ʒʁ]. In contrast, there are no restrictions for clusters generated through preverb /ʃ-/ affixation. In fact, this often generates clusters that are quite unnatural for Iron, including [ʃf], [ʃs],[19] [ʃχ], and [ʃl], which don’t occur in monomorphemic clusters.

Additionally, derived clusters do not require homogeneous voicing or show voicing assimilation. For example, both [ʃd] ([ˈʃda.vɨn] ‘to take up’) and [ʃz] ([ˈʃzu.rɨn] ‘to pronounce PERF’) occur without assimilation. While monomorphemic clusters are highly restricted, derived clusters with this preverb are exempted from these voicing and composition restrictions.

Aspiration also differs between monomorphemic and derived clusters. Voiceless stops are generally aspirated (syllable initially) or released (syllable finally), but are unaspirated in monomorphemic clusters. In

[18] As a note, compound verbs do not form prosodic words (c.f. complex predicates in (8a)). While complex predicates act as a prosodic word and stress one syllable in the entire complex predicate, compound verbs show primary stress on each word in the compound verb. In addition, when the preverb is added to complex predicates it is added before the non-verbal element (see 19). Conversely, in compound nouns, the preverb is added before the verbal element instead but can often resyllabify in coda position of the preceding noun.

[19] The word /səwɨn/ ‘to go’ can be produced as /ʃʃəwɨn/ or /ʃsəwɨn/ ‘to go up’. This is abnormal. In other cases like /ʃsɨmɨn/ ‘to drink up’, /ʃʃɨmɨn/ is not a possible pronunciation.

other words, if a voiceless stop is adjacent to another consonant in a monomorphemic word, it is unaspirated. Conversely, in preverb derived clusters, voiceless stops remain aspirated (19). For example, compare the aspiration of [t] in the preverb derived cluster [ˈʃtʰə.χɨn] ‘to fly up’ (which retains aspiration) to the [t] in the monomorphemic cluster [ʃtəg] ‘bone’ which is unaspirated. This pattern was consistent in elicited data and cited in work by Hettich (2002) and Abaev (1964). In summary, the preverb derived clusters have few to no compositional restrictions, and onset segments are not sensitive to the presence of the preverb and do not undergo voicing assimilation or lose aspiration. These facts indicate that the preverb does not interact with following segments in derived clusters.

(19) Clusters formed with the preverb /ʃ-/

Infinitive		*/ʃ-/ Preverb*	*Gloss*
tʰəˈχɨn	⟶	ˈʃtʰə.χɨn	‘to fly up’
ˈtʰu. χɨn	⟶	ˈʃtʰu.χɨn	‘to fold/wrap PERF
ˈda.vɨn	⟶	ˈʃda.vɨn	‘to take up’
kʰə.ˈnɨn	⟶	ˈʃkʰə.nɨn	‘to do PERF
kʰə.ˈʃɨn	⟶	ˈʃkʰə.ʃɨn	‘to look up’
ˈkʰa.fɨn	⟶	ˈʃkʰa.fɨn	‘to rise to dance’
fɨ.ˈsɨn	⟶	ˈʃfɨ.sɨn	‘to bake PERF’
fəl.ˈda.χɨn	⟶	ˈʃfəl.da.χɨn	‘to fold upward’
sɨ.ˈmɨn	⟶	ˈʃsɨ.mɨn	‘to drink up’
ˈzu.rɨn	⟶	ˈʃzu.rɨn	‘to say/pronounce PERF’
ˈʃu.rɨn	⟶	ˈʃʃu.rɨn	‘to pursue/chase upwards’
ʃə.ˈri.bar kʰə.nɨn	⟶	ˈʃʃə.ri.bar kʰə.nɨn	‘to become free PERF’
χəʃ.ˈʃɨn	⟶	ˈʃχəʃ.ʃɨn	‘to raise PERF’
lə.ˈwɨn	⟶	ˈʃlə.wɨn	‘to stand up’
lɨg ˈkʰə.nɨn	⟶	ˈʃlɨg kʰə.nɨn	‘to cut’
wəʁt ˈkʰə.nɨn	⟶	ˈʃwəʁt kʰə.nɨn	‘to let loose PERF’

Notably, when the preverb is affixed to a stem that already contains a cluster, an epenthetic vowel [ɨ] is inserted following the preverb. Epenthesis occurs regardless of whether the stem contains a strong or weak vowel as shown in (20). As noted above, the syllable containing the preverb is stressed, even with an epenthetic vowel. This is the only situation in which the preverb is sensitive to the contents of the onset. Iron does not allow three consonants in a cluster initially, which would occur if the preverb were attached directly to an initial monomorphemic cluster. Epenthesis of /ɨ/ prevents this violation and results in resyllabification of the initial consonant in the monomorphemic cluster into the coda position of the now initial syllable. Notably, epenthesizing a vowel would eliminate the CCC cluster whether it occurred after the preverb, which would resyllabify as [ʃɨC.CV], or before the preverb, which would syllabify as [ɨʃC.CV]. However, epenthesizing after the preverb provides an option that eliminates all word medial clusters (e.g. [ʃɨC.CV]), potentially making this the preferred epenthesis location due to Iron’s general dispreference for medial clusters.

(20) The /ʃ-/ preverb affixed to words with a complex onset and weak vowel

Infinitive		*Preverb*	*Gloss*
ˈʃtə.rɨn	⟶	ˈʃɨʃ.tʰə.rɨn	'to lick up'
ˈʃk'ə.rɨn	⟶	ˈʃɨʃ.k'ə.rɨn	'to drive up'
ˈʃkʷ'ɨ.nɨn	⟶	ˈʃɨʃ.kʷ'ɨ.nɨn	'to tear PERF'
ˈʃqi.wɨn	⟶	ˈʃɨʃ.qi.wɨn	'to fly out/pop off PERF'
ˈʃka.rɨn	⟶	ˈʃɨʃ.ga.rɨn	'to investigate/feel around EMPH'
ˈʃmu.dɨn	⟶	ˈʃɨʃ.mu.dɨn	'to sniff upward'
ˈʒmən.tɨn	⟶	ˈʃɨʒ.mən.tɨn	'to agitate/mix PERF'
ˈʒdu.χɨn	⟶	ˈʃɨʒ.du.χɨn	'to twist upward'
ˈʒdə.χɨn	⟶	ˈʃɨʒ.də.χɨn	'to return PERF'
ˈʒʁə.lɨn	⟶	ˈʃɨʒ.ʁə.lɨn	'to have small pieces fall off PERF'
ˈʒʁa.lɨn	⟶	ˈʃɨʒ.ʁa.lɨn	'to pick pieces off something PERF'

Thus, there are clear behavioral differences between monomorphemic and derived clusters, and such differences must be accounted for in the analysis of monomorphemic clusters. However, determining how each should be modeled is a more difficult task. Arguably monomorphemic clusters beginning with [ʃ] and the clusters derived from the preverb /ʃ-/ both fit the description of *s*C clusters.[20] These types of clusters are crosslinguistically suspect because they commonly show divergent behavior compared to other types of clusters and frequently feature falling sonority (e.g. *s*t), which should violate the commonly accepted Sonority Sequencing Principle (Goad 2012; Henke et al. 2012). In some analyses, the *s* of *s*C clusters is represented in an 'appendix' position which connects to some prosodic level not associated with the onset (Goldsmith 1990). In contrast, Goad (2012) and Kaye (1992) argue that the *s* of *s*C clusters syllabifies in coda position of preceding syllables. Finally, some work relies on the notion of an empty nucleus to explain the patterns of *s*C clusters, including for word initial *s*C clusters in work by Goad (2012). To establish that monomorphemic clusters are relevant for stress assignment, these alternative analyses must be ruled out for at least some number of monomorphemic clusters in Iron.

Recall that derived clusters always draw stress (17c), syllabify freely across word boundaries (18b), and ignore composition constraints such as voicing assimilation and aspiration allophony (19). Thus, it is abundantly clear that monomorphemic and derived clusters do not share the same structure, and any structural analysis for the preverb derived clusters cannot be extended to monomorphemic clusters. The rest of this section will evaluate how well the aforementioned structural analyses fit both the behavior of the derived and monomorphemic clusters.

First, the preverb's ability to resyllabify across word boundaries could indicate that the preverb syllabifies in coda position (as opposed to onset syllabification) akin to arguments by Goad (2012) and Kaye (1992). This type of analysis predicts that preverb derived clusters should not show well-formedness constraints in the onset (explaining that lack of interaction with following segments) but that they should be subject to well-formedness constraints in the coda position (Goad 2012). At this time, there is no apparent evidence that any such restrictions occur, regardless of whether the preverb syllabifies initially or finally in a word. One example of this comes from the compound verb [zwapp dət.ˈtɨn] 'to answer'. When the preverb is added, it directly attaches to the word final geminate to form [zwappʃ dət.ˈtɨn] 'to answer PERF' despite restrictions on geminates occurring in clusters. This indicates that there are no compositional restrictions when the preverb occurs in either the coda or onset. Clusters formed by preverbs are essentially isolated from any interaction with preceding or following consonants, and unlikely to be part of a coda syllabification analysis.

Notably, the coda syllabification analysis also cannot explain the behavior of monomorphemic clusters. Such an analysis would predict that the composition of monomorphemic sibilant clusters should prefer

[20] Here *s* stands for sibilants including [s], [ʃ], and [s̩] that are listed as 'appendices' or called 'extrametrical' in these analyses.

falling to rising sonority (Goad 2012). This is not the case, as Iron allows both rising sonority clusters (like [ʃn], [ʃm], [ʒn], and [ʒm]) and falling sonority clusters (like [ʃt'] and [ʒd]). Most importantly, there are cases where the initial consonant of a monomorphemic cluster resyllabifies as part of the coda of the preverb syllable in (20) and many examples of medial clusters in which the initial consonant syllabifies as a coda (e.g. [ˈaʃ.tʰəw] 'middle'). In both cases, the second segment of the purported 'cluster' shows aspiration and does not adhere to voicing assimilation (e.g. [ˈʃtə.rɨn] → [ˈʃɨʃ.**tʰ**ə.rɨn] and [ˈʃka.rɨn] → [ˈʃɨʃ.**g**a.rɨn]). Since the behavior of cluster segments changes when the initial consonant syllabifies in the coda of the preverb, it strongly suggests that a coda analysis of initial clusters is incorrect.

Next, we can evaluate whether an extrametrical analysis can explain the derived and monomorphemic cluster behavior. The lack of segment interaction in derived clusters does strongly support an analysis in which the /ʃ-/ preverb is extrametrical. The preverb could syllabify as an appendix that joins directly to either the syllable or prosodic word rather than being part of either the onset or coda. Since the epenthesis in (20) consistently follows the preverb /ʃ-/, it may be that the /ʃ-/ preverb is a left-edge extrametrical syllable with a null nucleus. This would make it the typological parallel of right-edge extrametrical syllables found in varieties of Arabic. In essence, the preverb is actually /ʃ-/ or /ʃɨ-/ and larger prosodic constraints determine the form (Goad 2012; Scheer & Szigetvári 2005). The analysis of the preverb could severely benefit from more examples, especially in larger phrases, and the analysis provided here is intended to be exploratory. However, what must be true, is that whatever analysis applies to the derived clusters cannot also apply to the monomorphemic clusters. If the evidence for the preverb points us towards an extrametrical analysis, it is unlikely to also explain the monomorphemic clusters. If the behavior and insensitivity of the preverb is due to its status as an extrametrical segment or syllable, we must also assume that if an initial consonant in monomorphemic cluster was similarly extrametrical, it should show similar extrametrical behavior. Since it does not, this analysis seems unlikely.

Both a coda syllabification and extrametrical explanation are unlikely explanations for the structure of initial monomorphemic clusters. However, that leaves the null nucleus analysis for further investigation. The null nucleus analysis is difficult to dispense with as an explanation for the behavior of monomorphemic complex onsets because there is no apparent evidence for or against it. In contrast, it has great explanatory power for the preverb syllabification. Consider that when /ʃ-/ is added to an initial consonant cluster, an epenthetic vowel appears (20). However, when the preverb resyllabifies word finally, the epenthetic vowel does not appear, even to break up a geminate cluster as in [zwappʃ dət.ˈtɨn] 'to answer PERF'. This may indicate that the only place an epenthetic vowel can occur is immediately following the preverb in the pre-specified null nucleus position. Greater lexical or prosodic constraints are needed to explain why the null nucleus is filled word initially but not word finally, but it does provide some evidence that the preverb does indeed feature a null nucleus. However, that also means that both the extrametrical or null nucleus explanations are equally compatible with the preverb behavior. The lack of allophony and voicing assimilation could occur either because of an intervening null nucleus or because the preverb (or whole preverb syllable with the null nucleus) is extrametrical.

It is notable that when illicit clusters are broken up (such as in preverb affixation epenthesis (20) or for illicit initial geminates (e.g. [əʃ.ˈʃə.ʒəm] 'twentieth'), the vowel that is inserted never breaks up a monomorphemic cluster. If monomorphemic clusters featured a null nucleus, you would expect a vowel to sometimes surface there. If the null nucleus is present in monomorphemic clusters, it is never realized as a vowel. In addition, the fact that monomorphemic clusters show adjacency effects (such as voicing assimilation) may serve as counter-evidence for the null nucleus analysis. Therefore, the initial monomorphemic clusters are not easily compatibility with alternative syllabification explanations, especially because these alternative explanations can be readily used to explain the behavior seen in derived clusters.

As a final note, the motivation for suggesting an alternative syllabification for initial clusters should be addressed as well. Although Goad (2012) and others argue that, crosslinguistically, *s*C clusters need special analyses, they do not generally make the same argument for clusters with [ʒ] or Cw clusters. Goad (2012) does state that sometimes the *s*C cluster analyses are extended to voiced counterpart of *s*, but only when they arise from assimilation. In Iron, voicing assimilation occurs in the second consonant (/ʃg/ → [ʃk]) and not the other way around, indicating that initial [ʒ] is not a result of voicing assimilation. Additionally, sequences of [ʃn] occur, where the [ʃ] does not assimilate to [ʒ]. Therefore, it is unlikely that clusters with initial ʒC fall into the category of *s*C clusters typologically. Importantly, in Iron, the behavior of monomorphemic clusters is identical whether they are formed with an initial ʃC, ʒC, or Cw. Even if initial ʒC clusters did require alternative syllabification analysis, that would leave Cw clusters untouched. Clusters with Cw also show aspiration allophony akin to what is seen in monomorphemic ʃC and ʒC clusters, do not resyllabify in compound nouns, and most importantly, share the same stress pattern. Thus, all monomorphemic clusters should show the same structure, in which case applying theoretical treatments generally reserved for *s*C clusters is more difficult. The simplest explanation to account for the behavior of all monomorphemic cluster types is that the monomorphemic clusters syllabify in the onset.

Finally, since monomorphemic clusters with initial sibilants do not have any behavioral cues to motivate alternative structure analysis, any assumption of their structural differences must be based solely on their status as falling sonority clusters. Henke et al. (2012), Wright (2004), and Steriade (2001, 2009) (among others) have argued that perceptual salience of segments by position better accounts for the typological distribution of cluster types, eschewing the need for the Sonority Sequencing Principle. Henke et al. (2012) argues that, in this view, initial sibilant clusters are actually a preferred cluster type since the cues for sibilants are exceptionally robust in position C_1 and do not rely on the presence of adjacent vowel formants for identification. In contrast, initial obstruents are less robust in clusters because many of their place of articulation cues are found in the adjacent formant structure (Henke et al. 2012). When obstruents occur in position C_1, they are often difficult to distinguish unless followed by a liquid, glide, or vowel. Interestingly, that means that clusters with an initial sibilant, like Iron's ʃC and ʒC clusters, and clusters with an approximant in position C_2, like Iron's Cw clusters, are perceptually ideal. Under this account, then, these monomorphemic clusters are predicted to occur, rather than being structurally problematic. This discussion, in addition to the evaluation of the behavior of derived clusters and potential explanations for such behavior, strongly points us towards accepting monomorphemic clusters as true onset clusters.

7 Allophonic distribution of clusters and labialized consonants

Until this point, the paper has focused mostly on clusters with a postalveolar fricative in position one. This section will take a brief excursus to examine the behavior of Cw clusters and labialized consonants in Iron. As mentioned previously, Iron features both labialized consonants and clusters containing a consonant and [w]. Despite the fact that they are both represented with 'w' (Cyrillic 'y') in the orthography, labialized consonant and Cw clusters appear to be in allophonic distribution. Only velar and uvular consonants can be labialized and the C in Cw clusters can never be velar or uvular. Words with Cw clusters in the initial syllable feature first syllable stress regardless of their vowel (21). In this way, Cw clusters act identically to postalveolar fricative clusters.

(21) Cw clusters

Singular		*Plural*	*Gloss*
ˈdwar	⟶	ˈdwərt.tə	'doors'
ˈbwar	⟶	ˈbwərt.tə	'skins'
ˈʃwar	⟶	ˈʃwərt.tə	'Springs'
ˈswan	⟶	ˈswənt.tə	'hunts'
ˈzwapp	⟶	ˈzwəp.pɨ.t^{h}ə	'answers'
ˈzwar	⟶	ˈzwərt.tə	'shrines/angels'

Since the singular examples in (21) contain the strong vowel [a], the pattern of first syllable stress could be attributed to an underlying strong vowel. However, this is not the case. Other examples of reduction, such as [kʰəl.ˈmɨ.tʰə] ‘snakes’ or [məʁʒ.ˈtʰə] ‘brains’ contain [a] in the singular ([kʰalm] ‘snake’; [maʁʒ] ‘brain’), but neither receive initial syllable stress on the reduced vowel. This indicates that the vowel in the singular form does not have an effect on stress in the plural and the initial syllable stress in (21) is caused by the cluster.

Conversely, words with initial labialized consonants and weak vowel (22) show consistent second syllable stress. Therefore, labialized consonants pattern as simplex onsets. Since Cw clusters always pattern as a complex onset (21), we can conclude that Cw has two fully realized segments, but labialized consonants are a single segment with a secondary articulation point.

(22) Words with labialized consonant onsets

Singular		*Plural*	*Gloss*
qʷɨ.ˈmas	⟶	qʷɨ.ˈmas.tʰə	‘fabrics’
ˈqʷɨr	⟶	qʷɨr.ˈtʰə	‘throats’
ˈχʷɨŋk’	⟶	χʷɨn.ˈʧ’ɨ.tʰə	‘holes’
ˈχʷɨ	⟶	χʷɨ.ˈtʰə	‘pigs’
ˈkʷɨz	⟶	kʷɨz.ˈtʰə	‘dogs’
ˈkʷɨrm	⟶	kʷɨrm.ˈtʰə	‘the blind ones’ (blind PL)
ˈgʷɨl	⟶	gʷɨl.ˈtʰə	‘pastries’
ˈgʷɨr	⟶	gʷɨr.ˈtʰə	‘torsos’

When prompted, the consultant referred to the [w] in Cw clusters as a “diphthong.”[21] Following this clue, it is possible that [w] in Cw clusters could syllabify as part of the nucleus. In this case, the stress pattern shown in (21) could be attributed to a heavy nucleus rather than a complex onset.

If the [w] *consistently* syllabifies in the nucleus, words with initial [w] and a weak vowel should show first syllable stress due to the heavy nucleus (23). However, only one word of this type features first syllable stress, while the wide majority feature second syllable stress. Notably, the word [ˈwə.mɨn] ‘vomit’ is in free variation with another form [ˈo.mɨn], which has an initial strong vowel. It is likely that the free variation between these forms is responsible for the alternate stress pattern, and it is an outlier. In almost all cases, the initial [w] does not result in a heavy nucleus or word initial stress.

(23) Words with [w] onsets

IPA	*Gloss*
wə.ˈrɨkk	‘lamb’
wə.ˈtʰər	‘herd of cows’
wə.ˈlɨ.mə	‘up’
wə.ˈli.bəχ	‘cheesy flatbread’
wɨ.ˈnaf.fə	‘advice’
wɨt.ˈtə	‘spirits’
wɨ.ˈnɨn	‘to see’
wɨʃ.ˈʤɨn	‘married man’
ˈwə.mɨn / ˈo.mɨn	‘vomit’

[21] The consultant showed great metalinguistic awareness and specifically referred to it as a “diphthong.” When probed further, he was unable to clarify if he meant that these sequences had two segments (cluster) or just two targets (diphthong). He also referred to other sequences of a glide plus vowel (like /ja/) as diphthongs. Importantly, the vowels [u] and [o] can reduce to [wɨ] and [wə] respectively in unstressed positions in longer sentences. Calling them diphthongs may be related to this fact.

Of note, we collected one example with the /ʃ-/ preverb and initial Cw cluster: [ˈʃnwa.ʒɨn] 'to drink'. In this case, no epenthetic vowel appears, which differs from examples in (20). This should violate the phonotactic restrictions on initial three consonant clusters. More data is needed to confirm this is representative of a larger pattern. We may speculate that the extrametrical properties of the /ʃ-/ preverb allows triconsonantal ʃ-Cw clusters, but this would not explain why epenthesis happens with other clusters. It is also notable that the epenthetic vowel also does not occur when the preverb syllabifies in the coda as in [zwappʃ dət.ˈtɨn] 'to answer PERF'. Therefore, there may be some larger alternative explanation or facts that determine when the epenthetic vowel is inserted and when it is not. It is also possible that [w] is ambiguously syllabified and can form either a complex onset or heavy nucleus, akin to what is seen in Mandarin (Yip 2003). The second syllable stress clearly indicates that [w] syllabifies as a simplex onset before a weak vowel (23). Additionally, [w] may potentially syllabify in the nucleus to avoid triconsonantal clusters. Finally, it is possible that derived triconsonantal clusters with two sonorants (here [nw]) are acceptable. More data is needed. However, it is clear that initial Cw clusters pattern like complex onsets for stress assignment (c.f. Section 5).

8 OT analysis of Iron stress

It is clear that the generalizations from previous works do not fully capture the intricacies of stress in Iron. Evidence from Sections 5 and 7 suggests that a new generalization is required to explain stress in Iron. The new generalization follows: Stress in Iron is limited to the first foot at the left edge of a prosodic word. Iron syllables can be either heavy (bimoraic) or light (monomoraic). Heavy syllables contain a strong vowel or complex onset (initial consonant cluster). Light syllables contain neither. Bimoraic (heavy) syllables at the left edge of the word constitute a foot. Light (monomoraic) syllables at the left edge of the word must form feet with adjacent syllables. There are no apparent superheavy syllables.[22] The syllable types and their weights are presented below in Table 3. Codas are not relevant to syllable weight for stress assignment and are not included in the syllable types. Therefore, you can add any number of coda consonants to the syllable types listed in Table 3 below and the generalization still holds. While codas are not relevant for stress, there is evidence that they are relevant for word minimality. This is discussed in Section 8.4.

Stress assignment is simple and follows an iambic pattern. Since stress only occurs in the first two syllables of a prosodic word, we can surmise that each word only forms one foot at the left edge of the word. Stress occurs on the leftmost (and only) foot of the prosodic word. If that foot is bisyllabic, stress will occur on the rightmost syllable of that foot. Specifically, an initial heavy syllable constitutes a foot and will receive stress (ˈH) regardless of the syllabic structure of the rest of the word. A word with two light initial syllables will form a foot with both syllables. The second syllable is then stressed in that foot (L ˈL). A word with an initial light syllable and heavy second syllable is slightly more complicated. The most common foot type in an iambic system contains a light syllable and then heavy which receives stress (L ˈH) (Hayes 1995). Since the initial syllable cannot form a bimoraic foot on its own, it forms a foot with the adjacent syllable (creating a trimoraic foot). This allows the foot to occur at the leftmost edge of a word and still produce stress on the second syllable of that word. Now that the generalization is established, Section 8.1 details what constraints are required to achieve the appropriate weights for different syllable types. Then Section 8.2 presents OT tableaux for assigning moras, footing, and stressing.

[22] Thank you to multiple reviewers who pointed out that superheavy syllables may exist, but that the language is not sensitive to the difference between two and three moras. In fact, removing the constraint that disprefers superheavy syllables from this analysis would change the moraic representation of certain syllables, but would not result in divergent stress predictions. A superheavy initial syllable would form its own foot and be stressed in exactly the same way as a heavy syllable. Superheavy syllables cannot occur outside the first syllable because of the phonotactic restrictions in Iron. The analysis here retains the superheavy syllable restriction for simplicity.

Table 3: Syllable types in Iron

Light	Heavy
v_{WEAK}	V_{STRONG}
Cv_{WEAK}	$\text{CV}_{\text{STRONG}}$
	CCv_{WEAK}
	$\text{CCV}_{\text{STRONG}}$

8.1 Developing an OT account of stress

While the generalization for stress is clear, establishing an OT analysis is not as straightforward. Previous OT analyses for onset sensitive systems often utilize alignment considerations (to force stressed syllables to have an onset) or constraints that penalize onsets that are not moraic (Topintzi 2010). Most frequently, high ranking constraints like $\text{WBP}_{\text{[ONS]}}$ or $\text{BEMORAIC}_{\text{[ONS]}}$ are used to coerce moraic onsets (Kager 1999; Topintzi 2010; Topintzi & Nevins 2017). In their classic usage, these constraints are insensitive to the contents of the onset, and simply penalize the presence of non-moraic onsets. Thus, onsets will be moraic unless a higher ranking constraint intercedes. These constraints easily explain systems where onset presence contributes to weight. However, they cannot explain one where onset complexity plays a role.

To create a system sensitive to onset complexity, it is tempting to utilize a constraint that looks at each consonant in the onset and evaluates whether it is moraic. Both an additive $\text{WBP}_{\text{[ONS]}}$ implementation or constraint from the *APPEND family (Rosenthall & Van Der Hulst 1999) that penalizes consonants not attached to a mora could easily generate a system in which each non-moraic consonant in the onset is penalized. In fact, this analysis was proposed by Topintzi (2010) as a way of accounting for additive onset (or coda) complexity sensitivity in languages. For Iron, such a system would correctly predict that two consonants in the onset are heavier than one consonant in the onset (CCV $>$ CV), but would incorrectly assume that the presence of an onset is heavier than the absence of one (CV $>$ V).

We can also further evalute the assumptions such an analysis would generate in Iron. One problem with such an additive moraic consonant analysis comes from Cv_{WEAK} syllables, which are light in Iron. If each onset consonant must attach to a mora, this predicts Cv_{WEAK} have a moraic onset, but that the vowel must be non-moraic because the syllable is light. In addition, this indicates that both moras of CCv_{WEAK} (a heavy syllable) must occur in the onset. Finally, in a light $\text{Cv}_{\text{WEAK}}\text{C}$ syllable, the rime would provide no weight since onsets must be moraic and the syllable only contains one mora, violating the assumptions of rimal primacy (Gordon 2006). This extremely marked pattern would be required throughout the language. While it could be argued for, the typological rarity and markedness of such a system makes it seem unlikely.

In addition, it seems strange to argue for an analysis where each onset consonant is moraic when simplex onsets appear to be prosodically inert. Only complex onsets play any role in stress assignment. Thus, the constraint should categorically separate simplex and complex onsets. There are many languages in which the composition of the onset affects moraic status (i.e. languages sensitive to onset quality). For example, in Pirahã, voiceless onsets are considered moraic but voiced onsets are not (Topintzi 2010; Gordon 2005). Systems that are sensitive to onset quality assign moraic weight through constraints like $*\mu|\text{ONS}_{[+\text{voice}]}$ (penalize voiced onsets that are moraic) above constraints which coerce moraic onsets like $\text{WBP}_{\text{[ONS]}}$ (Topintzi 2010). If constraints can examine the composition of onsets to determine weight by voicing, they should also be able to do so by examining complexity, especially if complexity provides perceptual benefits that resemble effects of voiceless onsets (for discussion see Gordon (2005) and Ryan (2014)). Therefore, I propose a modified constraint which penalizes moraic simplex onsets called $*\mu|\text{ONS}_{\text{[SIMPLEX]}}$.[23] This constraint determines if onsets are simplex or complex and allows onsets to carry zero or one mora. Moraic simplex

[23] During the review process, a paper authored by Topintzi (2022) was published arguing for a constraint that assigns moraic structure to complex onsets called $\text{WBP}_{\text{COMPLEXONS}}$. This constraint also allows complex onsets to bear moras while prohibiting simplex moraic onsets. There is a theoretical discrepancy between the two constraints since one requires complex onsets to be

onsets are penalized by the constraint $*\mu|\text{ONS}_{[\text{SIMPLEX}]}$ which is ranked above $\text{WBP}_{[\text{ONS}]}$. Therefore, moraic simplex onsets will receive a fatal violation which outranks the violation of non-moraic onsets.

Onset weight is addressed, but vowel weight by type remains. Iron represents a language in which weight is based on the full vs. reduced distinction discussed in Gordon (2006). Strong vowels in Iron are 'full' while the weak vowels are 'reduced' underlying short central vowels. In these types of systems, syllables with full vowels are always considered heavy, while syllables with reduced vowels can only be heavy when coerced by consonants (Gordon 2006). This analysis assumes that strong vowels are bimoraic while weak vowels are monomoraic, which is a common approach for systems with full vs. reduced or long vs. short vowels.

There is plenty of language internal evidence for bimoraic strong vowels. First, strong vowels in Iron are approximately double the length of weak vowels (Abaev 1964; Hettich 2002). In addition, they show relatively less acoustic variation than weak vowels (Hettich 2002). Finally, strong vowels with no onsets or codas still draw stress in the first syllable (e.g. /ˈa.tʲe/ 'outside' & /ˈa.fon/ 'epoch'). This means they are considered heavy for the purposes of assigning stress without consonants. For a vowel-only syllable to be heavy, the vowel must be minimally bimoraic.

Weak vowels must be lighter than strong vowels, but could potentially be monomoraic or moraless. In many ways, weak vowels pattern as moraless vowels similar to schwa or central vowels in other languages (Shih 2018; Kager 1989; Hyman 1985; Crosswhite 1999). Mora-less central vowels often show minimal duration and large variance in quality (Shih 2018). Both weak vowels in Iron are central, highly variable in production, and shorter in duration than their strong vowel counterparts (Hettich 2002). Weak vowels are also prone to deletion when adjacent to strong vowels which could be attributed to a mora-less status (Abaev 1964; Hettich 2002). However, languages with moraless central vowels generally also admit monomoraic vowels (e.g. Dutch). Allowing moraless and bimoraic vowels without also admitting monomoraic vowels is currently unattested and strange, making this analysis unlikely. In addition, when two weak vowels are adjacent across word boundaries, they frequently merge to form one strong vowel. For instance, when joined, the words [mə] 'my' and [əm.ˈbal] 'friend' form [ˈmʲem.bal] 'my friend'. This is easily explained by two weak monomoraic vowels merging to make one bimoraic vowel (which is coerced to be the strong vowel [e]). Therefore, bimoraic strong vowels and monomoraic weak vowels are most likely.

Following Topintzi (2010) and Rosenthall & Van Der Hulst (1999), moras are assigned to strong vowels in the input. This is a common practice for long vowels which are assumed to be lexically specified for either multiple timing positions or moras (Hayes 1989; Gordon 2006). Here it is utilized for only the strong vowels under the same rationale. Weak vowels are not lexically specified in the input, but are assigned a mora through the use of a high ranking constraint V-μ (Rosenthall 1994). V-μ penalizes vocalic nodes not associated with a mora. The current data indicates that all weak vowels are monomoraic but it is possible for V-μ to be outranked and coerce moraless vowels if they appear in future data. The fidelity of strong vowel weight is ensured by the weight identity constraint WT-ID. In its original usage, WT-IDENTITY states that monomoraic input vowels are monomoraic in the output and bimoraic input vowels are bimoraic in the output. Since only strong vowels are specified on input, this constraint only interacts with strong vowels.[24] Essentially, a strong vowel which is specified as bimoraic on the input should be bimoraic on output. Based on current data, this constraint must be highly ranked since it is never violated. Surface strong vowels are always heavy.[25]

Finally, there is no apparent weight difference between the various types of heavy syllables, and such

moraic and one prohibits simplex onsets from being moraic, but they functionally cause the same outcome. This will be further discussed in Section 9. In either case, it adds support to the claim that constraints can be sensitive to the complexity of an onset.

[24] The same effect could be attributed to constraints like Maxμ or Depμ which ensure moraic faithfulness.

[25] Strong vowels often reduce. When a reduced vowel occurs in a word, it acts identically to an underlyingly weak vowel. For more discussion of when reduction occurs, see Section 8.5. The presence of reduction indicates that the WT-ID constraint is not undominated. Some higher ranking constraint must allow the reduction of strong vowels and loss of a mora without affecting stress assignment, which then follows naturally. This may be related to the durational length of syllables, as described in Section 8.5.

a difference would be almost impossible to see. The stress window in Iron is limited to the first full foot at the left edge of the word. Therefore, if the first syllable is heavy, it will always receive stress. Vowel reduction does occur but seems to be more strongly connected to word length than moraic structure (see Section 8.4). The lack of apparent differences between the various syllable types indicates that syllables may be maximally bimoraic or at least insensitive to superheavy status. Thus, this analysis will also include a constraint that penalizes superheavy syllables called SYLLSIZE[26] (Rosenthall & Van Der Hulst 1999). This avoids behavioral predictions for potentially superheavy syllables.

Based on the patterns and constraints explained above, we expect syllables to have the moraic structure outlined in Table 4. Superscripted moras appear after the syllable position that bears them. Syllables with a weak vowel will contain only one mora unless they also contain a complex onset. A complex onset before a weak vowel will also contribute a mora. Syllables with a strong vowel are maximally bimoraic. Since the vowel is bimoraic, onsets never contribute a mora regardless of complexity. The next section will provide tableaux to show how the interaction of the constraints results in the moraic structure for CV skeleta shown in Table 4.

Table 4: Syllable types in Iron with moras

Syllables with Weak Vowels	Syllables with Strong Vowels
v^{μ}	$V^{\mu\mu}$
Cv^{μ}	$CV^{\mu\mu}$
$CC^{\mu}v^{\mu}$	$CCV^{\mu\mu}$

8.2 Assigning moraic structure tableaux

The constraints utilized in this analysis are listed and defined below. Some constraints are crucially ranked. Notably, some are apparently inviolable and thus must be highest ranked. For instance, we have no examples of monomoraic strong vowels or overt moraless weak vowels so WT-ID and V-μ must be ranked highest. Additionally, codas do not appear to ever contribute moras, even to satisfy word minimality.[27] Therefore, the constraint *μ|CODA must also be highly ranked and essentially inviolable. However, to generate a system where onsets prefer to be moraic, but simplex onsets do not contribute a mora, *μ|ONS$_{[\text{SIMPLEX}]}$ must outrank WBP$_{[\text{ONS}]}$. To avoid superheavy syllables caused by moraic onsets, SYLLSIZE must outrank WBP$_{[\text{ONS}]}$. There is no clear impetus to rank *μ|ONS$_{[\text{SIMPLEX}]}$ and SYLLSIZE.

WT-ID
: Strong vowels should be bimoraic (Rosenthall & Van Der Hulst 1999)

V-μ
: Vocalic nodes should be associated with a mora (Rosenthall 1994)

*μ|CODA[28]
: Penalize moraic codas (Topintzi 2010)

SYLLSIZE
: A syllable can maximally contain two moras (Rosenthall & Van Der Hulst 1999)

[26] Another possible constraint to use here is *$\mu\mu\mu$ from Prince & Smolensky (2004). This constraint penalizes syllables with 3 moras. However, SYLLSIZE is employed instead because it penalizes any amount of moras greater than two.

[27] Codas help words meet minimality requirements, but not through coerced moraic structure. See Section 8.4 for discussion.

[28] It is possible to use a broader constraint that penalizes all moraic consonants to achieve the same result. Such a constraint would necessarily be ranked lower than WBP$_{[\text{ONS}]}$ to allow moraic complex onsets to occur. In fact, it would also be useful for encouraging medial clusters to syllabify across syllable boundaries to avoid being moraic. However, since codas appear to be prosodically inert, the specific constraint prohibiting them from being moraic is used here.

$*\mu|\text{ONS}_{[\text{SIMPLEX}]}$
Penalize moraic onsets that are simplex (modified from Topintzi (2010))

$\text{WBP}_{[\text{ONS}]}$
A categorical constraint that the onset position must be linked to a mora (Topintzi 2010)

$$\text{WT-ID, V-}\mu, *\mu|\text{CODA} >> \text{SYLLSIZE}, *\mu|\text{ONS}_{[\text{SIMPLEX}]} >> \text{WBP}_{[\text{ONS}]}$$

These constraints are first applied to syllables with strong vowels and either simplex (24) or complex onsets (25). Strong vowels are specified as bimoraic on input, so the high ranked WT-ID prevents any forms from surfacing without a bimoraic strong vowel. The moraic status of the onset is then determined by the constraint SYLLSIZE which prevents syllables from having more than two moras. Since SYLLSIZE is ranked above $\text{WBP}_{[\text{ONS}]}$, onsets will never be moraic when a strong vowel is present. The constraints select the form that maintains the correct vowel weight for strong vowels and reject any forms that are superheavy in both (24) and (25).

(24) Strong vowel with simplex onset: $/\text{CV}^{\mu\mu}/ \longrightarrow [\text{CV}^{\mu\mu}]$[29]

	$/\text{CV}^{\mu\mu}/$	WT-ID	SYLLSIZE	$*\mu\|\text{ONS}_{[\text{SIMPLEX}]}$	$\text{WBP}_{[\text{ONS}]}$
a.	CV	*!			*
b.	CV^{μ}	*!			*
c.	$\text{C}^{\mu}\text{V}^{\mu\mu}$		*!	*!	
d. ☞	$\text{CV}^{\mu\mu}$				*

(25) Strong vowel with complex onsets: $/\text{CCV}^{\mu\mu}/ \longrightarrow [\text{CCV}^{\mu\mu}]$ [30]

	$/\text{CCV}^{\mu\mu}/$	WT-ID	SYLLSIZE	$*\mu\|\text{ONS}_{[\text{SIMPLEX}]}$	$\text{WBP}_{[\text{ONS}]}$
a.	CCV	*!			*
b.	CCV^{μ}	*!			*
c.	$\text{CC}^{\mu}\text{V}^{\mu\mu}$		*!		
d. ☞	$\text{CCV}^{\mu\mu}$				*

These constraints also easily determine the appropriate candidate for syllables with weak vowels and a complex (26) or simplex onset (27). Recall that while CCv_{WEAK} is heavy, Cv_{WEAK} should be light. In both syllable types, any candidate that does not assign a mora to the weak vowel is eliminated by the high ranking constraint V-μ. Since no candidate in either (26) or (27) has more than two moras, no forms are eliminated by SYLLSIZE. In (26), the candidate with the moraic onset $\text{C}^{\mu}\text{v}^{\mu}$ receives a fatal violation from $*\mu|\text{ONS}_{[\text{SIMPLEX}]}$ which outranks the violation that the moraless onset receives from $\text{WBP}_{[\text{ONS}]}$. Thus the optimal candidate is a light syllable where the onset does not contribute a mora (Cv^{μ}). Crucially, in (27), no candidates are affected by $*\mu|\text{ONS}_{[\text{SIMPLEX}]}$ since no candidate features a simplex onset. In (27), the winning candidate is selected by $\text{WBP}_{[\text{ONS}]}$ which assigns a fatal violation to the form without a moraic onset CCv^{μ} leaving $\text{CC}^{\mu}\text{v}^{\mu}$ as the winning candidate. Syllables that consist of only a weak vowel are easily handled by the constraint V-μ (28). Moraless vowels violate this constraint, leaving the monomoraic candidate as

[29] Note that even if SYLLSIZE were not included, the candidate $\text{C}^{\mu}\text{V}^{\mu\mu}$ would still be eliminated by $*\mu|\text{ONS}_{[\text{SIMPLEX}]}$. Therefore, the only possible superheavy syllable would take the form $\text{CC}^{\mu}\text{V}^{\mu\mu}$.

[30] Without SYLLSIZE the superheavy candidate $\text{CC}^{\mu}\text{V}^{\mu\mu}$ would be optimal because of $\text{WBP}_{[\text{ONS}]}$.

optimal. Thus these constraints correctly generate a system in which Cv_{WEAK} and v_{WEAK} are both light and monomoraic. They also choose optimal forms for CCv_{WEAK}, CCV_{STRONG}, CV_{STRONG}, and V_{STRONG} that are heavy and bimoraic.

(26) Weak vowel with simplex onset: /Cv/ ⟶ [Cv^{μ}]

	/Cv/	V-μ	SYLLSIZE	*μ|ONS$_{[SIMPLEX]}$	WBP$_{[ONS]}$
a.	Cv	*!			*
b.	$C^{\mu}v$	*!		*	
c. ☞	Cv^{μ}				*
d.	$C^{\mu}v^{\mu}$			*!	

(27) Weak vowel with complex onset: /CCv/ ⟶ [$CC^{\mu}v^{\mu}$]

	/CCv/	V-μ	SYLLSIZE	*μ|ONS$_{[SIMPLEX]}$	WBP$_{[ONS]}$
a.	CCv	*!			*
b.	$CC^{\mu}v$	*!			
c.	CCv^{μ}				*!
d. ☞	$CC^{\mu}v^{\mu}$				

(28) Weak vowel with no onset: /v/ ⟶ [v^{μ}]

	/v/	V-μ
a.	v	*!
b. ☞	v^{μ}	

The preceding tableaux show that these constraints generate the appropriate weight for various syllables with onsets and different vowel types. Importantly, although these CV skeleta do not contain codas, these tableaux can be extended to forms that do contain codas. Such cases require inclusion of the constraint *μ|CODA which penalizes forms that assign moras to codas. Each of these CV skeleta could be rewritten as CV(C*) with an undominated *μ|CODA constraint. This would correctly result in a system in which codas are never moraic and the aforementioned optimal candidates would remain the same. Thus, a syllable's moraic structure is determined solely by the vowel quality and the onset complexity.[31]

8.3 Footing and stress assignment

For footing and stressing, well established constraints like SYLLABLEINTEGRITY, FTBINμ, and PARSE-SYLL are utilized. SYLLABLEINTEGRITY ensures moraic structure does not split syllables (Kager 1993). Bimoraic feet are established by FTBINμ, which is here interpreted to penalize any foot that is not bimoraic (targeting feet with fewer and greater than 2 moras). Additionally, PARSE-SYLL is employed to ensure syllables are parsed into feet. Since feet are minimally bimoraic and moras are restricted to their own syllables, this means heavy syllables will be parsed into their own foot, while light syllables must parse into feet with adjacent syllables. Ranking FTBINμ above PARSE-SYLL penalizes degenerate feet, meaning feet that are not bimoraic are generally dispreferred, but can occur if coerced (McCarthy & Prince 1993; Gordon 2011).

[31] The relationship between this analysis and Gordon's claims regarding rimal primacy are further discussed in Section 9.

The stress window in Iron is at the left edge of the prosodic word, and secondary stress does not occur. Thus, only one foot forms at the left edge of the prosodic word. This requires the constraint ALIGN-FT-LEFT which penalizes feet that are not on the left edge of the prosodic word (Kager 1999). The implementation of this can either be absolute or gradient (Kager 1999). A gradient analysis penalizes feet that are not initial based on how far away they are from initial position. An absolute implementation assigns a violation for every foot that is not initial, regardless of where it is in the word (Kager 1999). The gradient interpretation is utilized here to prevent feet from forming outside the initial two syllable window in longer words. Finally, words with two light syllables at the left edge of the word feature stress on the second syllable, which indicates that the right edge of a foot aligns with stressed elements. Employing the constraint HEAD-RIGHT ensures that, within a foot, the right-most syllable is stressed (Kenstowicz 2003). In monosyllabic feet, this constraint won't be apparent in surface forms. Together, the patterns described create a classic iambic stress pattern, where two light syllables (L ˈL), one heavy syllable (ˈH), or one light and then heavy syllable (L ˈH) can each form an iambic foot with right headed stress.

To explain the pattern in Iron with consistency, these must be crucially ranked. In general, there is a dispreference for feet greater than or smaller than two moras. However, this can be violated in the case of words with an initial light syllable followed by a heavy one. Here, ALIGN-FT-LEFT encourages that foot to occur at the left edge of the word, but FTBINμ penalizes both a monomoraic initial foot and a trimoraic two syllable foot. PARSE-SYLL can act as a tiebreaker to allow the iambic (L ˈH) foot. However, both FTBINμ and ALIGN-FT-LEFT are crucially ranked above PARSE-SYLL to account for the rest of the footing patterns. ALIGN-FT-LEFT must be ranked above PARSE-SYLL to avoid forming more than one foot in a word. Any foot that is not at the left edge of the word will be eliminated by ALIGN-FT-LEFT even if leaving the syllable unparsed violates PARSE-SYLL. For instance, in a word with an initial heavy syllable, all other syllables will violate PARSE-SYLL. However, the higher ranked ALIGN-FT-LEFT eliminates all candidates with more than one foot in the word, and candidates where the foot is not on the left edge. FTBINμ is also crucially ranked above PARSE-SYLL so that feet that are larger than or smaller than two moras (degenerate feet) will be penalized, even if the result leaves syllables unparsed.

Essentially, bimoraic feet at the left edge of the word are preferred. If the initial syllable is bimoraic, it forms its own foot. If not, it forms a foot with the adjacent syllable. Only one foot is formed in a word.[32] Finally, stress is then assigned to the rightmost syllable in the foot using HEAD-RIGHT, which is not crucially ranked. HEAD-RIGHT states that within a foot, the rightmost component that will be stressed, resulting in an iambic system. These constraints result in words with the foot structure shown in Table 5. A tableaux for each type is included below.[33]

Table 5: Footed syllables

Type	Structure	Example	Footed Example
Two Light syllables	$CV_{WEAK}CV_{WEAK}$	ləg.ˈtʰə	(ləg.ˈtʰə)
Two Heavy Syllables	$CV_{STRONG}CV_{STRONG}$	ˈkʰa.fag	(ˈkʰa)fag
	$CCV_{WEAK}CV_{STRONG}$	ˈʒmə.lag	(ˈʒmə)lag
Heavy then Light	$CV_{STRONG}CV_{WEAK}$	ˈgo.gɨʒ	(ˈgo)gɨʒ
	$CCV_{WEAK}CV_{WEAK}$	ˈʒmən.tɨn	(ˈʒmən)tɨn
Light then Heavy	$CV_{WEAK}CV_{STRONG}$	tʰə.ˈχag	(tʰə.ˈχag)

[32] Compound verbs, such as those seen in (18), can feature multiple stresses because they are multiple prosodic words. In contrast, a complex predicate like those in (8) form one prosodic word and thus feature only one foot at the left edge of the word.

[33] $CV_{WEAK}CCV_{WEAK}$ and $CV_{WEAK}CCCV_{WEAK}$ are not included because they avoid medial onset clusters in syllabification, resulting in $CV_{WEAK}C.CV_{WEAK}$ or $CV_{WEAK}CC.CV_{WEAK}$. Both, therefore, have two light syllables. Similarly, no forms with superheavy syllables are included as they cannot occur outside of word initial position and words with initial superheavy syllables may be treated identically to words with initial heavy syllables.

(29) Two light syllables: /ləg.tʰə/ ⟶ (ləg.tʰə)

/ləg.tʰə/			FTBINμ	ALIGN-FT-LEFT	PARSE-SYLL
a.	(ləg)(tʰə)	$(\mu)(\mu)$	*!	*!	
b. ☞	(ləg.tʰə)	$(\mu.\mu)$			
c.	(ləg)tʰə	$(\mu)\mu$	*!		*
d.	ləg(tʰə)	$\mu(\mu)$	*!	*!	*

(30) Two heavy syllables: /kʰa.fag/ ⟶ (kʰa)fag

/kʰa.fag/			FTBINμ	ALIGN-FT-LEFT	PARSE-SYLL
a.	(kʰa)(fag)	$(\mu\mu)(\mu\mu)$		*!	
b. ☞	(kʰa)fag	$(\mu\mu)\mu\mu$			*
c.	kʰa(fag)	$\mu\mu(\mu\mu)$		*!	*
d.	(kʰa.fag)	$(\mu\mu.\mu\mu)$	*!		

(31) Heavy then light: /go.gɨʒ/ ⟶ (go)gɨʒ

/go.gɨʒ/			FTBINμ	ALIGN-FT-LEFT	PARSE-SYLL
a.	(go)(gɨʒ)	$(\mu\mu)(\mu)$	*!	*!	
b. ☞	(go)gɨʒ	$(\mu\mu)\mu$			*
c.	go(gɨʒ)	$\mu\mu(\mu)$	*!	*!	*
d.	(go.gɨʒ)	$(\mu\mu.\mu)$	*!		

(32) Light then heavy: /tʰə.χag/ ⟶ (tʰə.χag)[34]

/tʰə.χag/			FTBINμ	ALIGN-FT-LEFT	PARSE-SYLL
a. ☞	(tʰə.χag)	$(\mu.\mu\mu)$	*		
b.	(tʰə)(χag)	$(\mu)(\mu\mu)$	*!	*!	
c.	(tʰə)χag	$(\mu)\mu\mu$	*		*!
d.	tʰə(χag)	$\mu(\mu\mu)$		*	*!

Once footing is established, HEAD-RIGHT ensures the rightmost syllable in the foot receives stress. Since most words only have a single bimoraic foot (e.g. (go)gɨʒ (31) and (kʰa)fag (30)) the footed heavy syllable receives stress. Words with that begin with a light syllable form bisyllabic feet based on the tableaux in (29) (e.g. (ləg.tʰə) forms (L ˈL)) and in (32) (e.g. (tʰə.χag) forms (L ˈH)). In these cases, HEAD-RIGHT selects the second syllable in the word to form the appropriate stress pattern in (33) and (34) .

[34] Vowel reduction does occur, but cannot occur on suffixes. This means that the higher ranking constraint that dictates when vowel reduction occurs prevents that form (tʰə.χəg) from surfacing, which would obviously be more ideal than the form that violates foot binarity here. For more details on the pattern of vowel reduction in Iron, see Section 8.5

(33) Assigning stress with two light syllables (ləg.tʰə) ⟶ (. *)

	(ləg.tʰə)		HEAD-RIGHT
a. ☞	(ləg.ˈtʰə)	(. *)	
b.	(ˈləg.tʰə)	(* .)	*!

(34) Assigning stress with one light then heavy syllable (tʰə.χag) ⟶ (. *)

	(tʰə.χag)		HEAD-RIGHT
a. ☞	(tʰə.ˈχag)	(. *)	
b.	(ˈtʰə.χag)	(* .)	*!

8.4 Minimal word tableaux

No investigation of stress is complete without also investigating minimal word size. The Prosodic Minimality Hypothesis argues that the minimal size of words in a language must be related to the minimal size of feet (which are generally bimoraic or bisyllabic) (Blumenfeld 2011; Garrett 1999). In other words, a language with bimoraic minimal feet should also require bimoraic lexical words (Blumenfeld 2011). Iron has a minimal foot size of two moras, which predicts that words should also be minimally bimoraic. However, this assumption is not borne out in the Iron data. Assuming bimoraic minimal words both underpredicts or overpredicts allowable words in Iron.

Requiring minimal words to be bimoraic should inherently allow words that consist of only a strong bimoraic vowel. This does not occur in Iron. In fact, words with a single vowel only occur when they are prosodically joined to larger phrases or feature epenthesis which hints they are subminimal (see Section 3.4 for more information). Additionally, words with the structure $Cv_{WEAK}C$ are monomoraic, but are acceptable words in Iron. However, not all subminimal feet are allowed to be minimal words. Neither Cv_{WEAK} or $v_{WEAK}C$ syllables can be words, despite the fact that they are no different from $Cv_{WEAK}C$ words in terms of moras. Minimal words can also take the form CCv_{WEAK} or $v_{WEAK}CC$. While CCv_{WEAK} is bimoraic and expected, $v_{WEAK}CC$ should be monomoraic and unacceptable. Therefore, minimal words in Iron clearly do not line up with minimal feet.

Iron is not unique in its apparent mismatch between minimal feet and minimal words. Both Blumenfeld (2011) and Garrett (1999) detail many languages in which this type of mismatch occurs. However, these works handle the mismatch in different ways. Blumenfeld (2011) and others utilize coerced moraic weight on onsets and codas to force minimal words to match minimal feet (Topintzi 2006; Bagemihl 1998). This is most commonly accomplished by ranking the constraint GRWD=PRWD above constraints penalizing moraic onsets or codas (in the case of bimoraic feet) or those preventing vowel epenthesis (in the case of bisyllabic feet) (Blumenfeld 2011; Kager 1999). This constraint assigns violations to minimal words that do not meet the minimal foot requirement and coerces moraic onsets, codas, or epenthesis to satisfy word minimality.

However, simply coercing moraic weight does not generate the appropriate predictions for allowable words in Iron. First, since $Cv_{WEAK}C$ words do occur, it predicts that either simplex onsets or codas can be moraic for word minimality. Ranking GRWD=PRWD above $*\mu|$ONS$_{[SIMPLEX]}$ coerces words of the form $Cv_{WEAK}C$ and Cv_{WEAK} to be bimoraic, predicting both are acceptable. Ranking GRWD=PRWD above $*\mu|$CODA similarly coerces bimoraic structure for both $CV_{WEAK}C$ and $V_{WEAK}C$ words, predicting they are both acceptable. In both cases, coercing onsets or codas to be moraic predicts an unacceptable word should be acceptable. Not allowing either to be moraic predicts that $Cv_{WEAK}C$ is unacceptable and should not occur. Finally, under this approach, there is no explanation why a bimoraic strong vowel cannot form a word (V_{STRONG}). Thus, coercing moraic weight cannot account for the distribution of minimal word types in Iron.

In contrast, Garrett (1999) argues word length is a much better predictor of word minimality. Minimal words are subject to durational (and thus segmental) requirements. Garrett (1999) proposes a family of constraints called BE(X)LONG which penalize minimal words that are below a certain number of segments (for discussion of the durational requirements of these constraints, see Garrett (1999)). Languages can set their minimal word to any length, but the most common minimal word types are BE(CV)LONG (two segments with a vowel), BE(CVX)LONG (three segments with a vowel), and BE(CVCV)LONG (two syllables). Importantly, the X in BE(CVX)LONG allows words with long vowels (CVV) or codas (CVC) to satisfy this constraint, since both result in similar duration. While coerced moraic structure overgenerates possible minimal words, BE(CVX)LONG does not. Since strong vowels are almost double the duration of weak vowels, they are durationally equivalent to long vowels and count as two segments (VV) for word minimality requirements. Therefore, we can generalize that all words in Iron minimally have three segments, one of which must be a vowel. Examples in (35) and (36) show that this generalization holds regardless of vowel type or syllable structure. For ease, strong vowels are written as VV while weak vowels are written as v.

(35) Disallowed minimal words

Structure	*Slots*	*Examples*
v	1	–
VV	2	–
Cv	2	–
vC	2	–

(36) Allowed minimal words

Structure	*Slots*	*Examples*
CVV	3	t^hu 'spit'
VVC	3	ad 'taste'
CvC	3	bɨl 'lip'
vCC	3	ərχ'ravine'
CCv	3	ʒɡə'rust'

The data in (36) suggests that minimal words simply require three segments, one of which is a vowel. This can be represented by the constraint BE(XVX)LONG.[35] This constraint penalizes words that have fewer than 3 segments and do not contain a vowel. Any form that violates this constraint (see (35)) is not a valid word. This is the only constraint necessary to exhaustively detail the possible minimal words in Iron (37). Words that violate this constraint are not allowed, while words that don't are fine. In summary, although syllable weight relies on a moraic analysis, minimal word requirements are better explained by a sensitivity to the duration of the word in terms of segments.

(37) Possible minimal words in Iron

			BE(XVX)LONG
a.	v_{WEAK}	(V)	*!
b.	V_{STRONG}	(VV)	*!
c.	Cv_{WEAK}	(CV)	*!
d.	$v_{WEAK}C$	(VC)	*!
e.	$Cv_{WEAK}C$	(CVC)	
f.	CV_{STRONG}	(CVV)	
g.	$V_{STRONG}C$	(VVC)	
h.	CCv_{WEAK}	(CCV)	
i.	$v_{WEAK}CC$	(VCC)	

[35] It is more accurate to say BE(XXX)LONG where at least one X must correspond to a vowel to explicitly allow vCC and CCv. To rule out CCC words, an additional constraint must be used that prevents consonants from acting as a nucleus for the syllable. However, since there is no functional difference between these analyses, I have chosen to name the constraint BE(XVX)LONG to represent the required length and vowel properties.

8.5 Vowel reduction

Vowel reduction has been mentioned in previous sections, but not thoroughly discussed. In part, this is because more data is needed. However, this section will briefly summarize what is known about vowel reduction and when it occurs. First, vowel reduction generally refers to the tendency of [a] and [o] in monosyllabic stems to become [ə] when affixes are added. Several examples of this are shown throughout the paper, including words like [ʒnag] 'enemy', [dwar] 'door', [swan] 'hunt', and [zwapp] 'answer' which reduce in the plural (e.g. [ˈʒnəg.tʰə] 'enemies', [ˈdwər.tʰə] 'doors', [ˈʃwər.tʰə] 'hunts', and [ˈzwəp.pɨ.tʰə] 'answers'). Notably, vowels never reduce when they are part of a suffix (e.g. [-ag]). This may be because of the density of suffix vowels (e.g. both [-ag] and [-əg] exist as productive suffixes).

Notably, reduction is seemingly unrelated to stress assignment. When a word with a simplex onset and strong vowel reduce, stress shifts to the second syllable as predicted by the now weak initial vowel. For instance, words like [maʁʒ] 'brain' and [kalm] 'snake' reduce to [məʁʒ.ˈtʰə] 'brains' and [kəl.ˈmɨ.tʰə]. When reduction occurs on words with complex onsets, stress is maintained on the first syllable, as shown in the examples from the paragraph above. Most importantly, both examples frequently occur. Reduction is not more or less common for base words with complex onsets compared to words with simplex onsets. There are plenty of examples of reduction leading to changing and maintaining the stressed syllable. This makes it seem unlikely that reduction is related in any way to stress or syllable weight, as syllables that should be heavier (i.e. strong vowels and complex onsets) reduce just as frequently as those that should be lighter (i.e. strong vowels and simplex onsets).

There may be a relationship between the number of segments in a word (its duration) and whether that word undergoes reduction when morphemes are added. Words with strong vowels and three consonants (in any position) are more likely to reduce in the plural, while words with two consonants or fewer generally don't reduce. For instance, [arm] becomes [ˈarm.tʰə] 'hands' and [bal] becomes [bal.tʰə] 'cherries'. Reduction does not occur in either example. In contrast, words like [ʃt'ol] become [ˈʃt'əl.tʰə] 'tables' in addition to the other previously mentioned examples in this section which all feature at least three consonants. However, this trend is not absolute and exceptions do occur in both directions. For instance, [mad] becomes [mət.tə] 'mothers' with reduction, while [ˈnoʃt] becomes [ˈnoʃ.tʰɨ.tʰə] without reduction.

Further work is needed to reveal the strength of this pattern. Notably, the inverse correlation between segment duration and number of segments is well established. It is a near universal pattern that the average duration of each individual segment decreases as the number of segments in a syllable or word increases. This fact would support the conclusion that strong vowels in words with more than 3 segments are durationally shorter, and thus susceptible to reduction. Reduction in shorter words like /mad/ → /mət.tə/ 'mothers' could additionally be related to frequency of use. A thorough acoustic and frequency based analysis is required to confirm this. In either case, the tendency of vowels to reduce is likely related to something above the level of stress, as stress is assigned following the proposed generalizations following all reduction tendencies, and it does not appear that there is any impetus to avoid vowel reduction to preserve stress.

8.6 A unified analysis?

In the analysis provided in this paper, stress is described as sensitive to moraic structure, while word minimality is sensitive to length or duration. Although each captures the behavior well, it raises the question of whether the behavior of stress and word minima can be accounted for with a single analysis. This section will evaluate how well a unified analysis would account for the distribution of stress and minimal words in Iron. First, we can evaluate whether a moraic analysis can appropriately be applied to word minimality. As previously stated, using moraic structure to explain word minimality comes with many problems, most notably the absence of V_{STRONG} words, while accepting other bimoraic structures (e.g. CCv_{WEAK}) and other monomoraic structures (e.g. $v_{\text{WEAK}}CC$ and $Cv_{\text{WEAK}}C$). It is possible to coerce a moraic system to work for word minimality, but it requires many stipulative constraints and typologically rare patterns.

It is simple to account for the presence of $\mathrm{v}_{\mathrm{WEAK}}$CC words by coercing complex codas to bear weight for the purpose of minimality by ranking GRWD=PRWD above constraints that penalize moraic codas. A constraint that penalizes moraic simplex codas would avoid licensing $\mathrm{v}_{\mathrm{WEAK}}$C words, which parallels the constraint against moraic simplex onsets. These would be ranked higher than GRWD=PRWD to allow $\mathrm{v}_{\mathrm{WEAK}}$CC and CC$\mathrm{v}_{\mathrm{WEAK}}$ words, but not C$\mathrm{v}_{\mathrm{WEAK}}$ or $\mathrm{v}_{\mathrm{WEAK}}$C words. However, these constraints create a new problem. Neither simplex codas nor onsets can contribute weight for minimality, but words with a simplex onset *and* coda are allowed. A simplex onset or coda must be coerced to bear weight only when *both* an onset and coda are present. To satisfy bimoraic word minimality, the co-occurrence of onset and coda must somehow be linked to an additional mora, despite their non-adjacency.

However, the most problematic aspect of a moraic based account for word minimality is the lack of words containing only a single strong vowel. Strong vowels are inherently bimoraic. If a minimal word must be bimoraic, a strong vowel is a perfectly valid minimal word. The fact that this doesn't occur, indicates that words are *not* minimally bimoraic. It may be possible to assume that minimal words must be trimoraic. Indeed, trimoraic minimal words have been argued to exist in Gilbertese (Blevins & Harrison 1999) and Estonian (Hayes 1989). Then the absence of single vowel words but presence of C$\mathrm{V}_{\mathrm{STRONG}}$, $\mathrm{V}_{\mathrm{STRONG}}$C, and C$\mathrm{v}_{\mathrm{WEAK}}$C could be attributed to coerced moraic weight for every consonant. Similarly, both consonants in a complex onset (CC$\mathrm{v}_{\mathrm{WEAK}}$) or coda ($\mathrm{v}_{\mathrm{WEAK}}$CC) must be moraic to satisfy a trimoraic word minimality. Under this approach, a simplex onset or coda combined with a weak vowel forms a bimoraic word, which does not satisfy trimoraic minimality. In contrast, a simplex onset or coda with a strong vowel or a complex onset or coda with a weak vowel would all form trimoraic words in the context of word minimality. However, this would also predict that words like /ˈʒnaɡ/ 'enemy' would have five moras, which is unlikely (to say the least). Therefore, such a pattern would also need a constraint capping the number of moras in a minimal word after coercing every consonant to be moraic. Thus, this analysis is indeed a possible way to unify the analyses for word minimality and stress, but would represent a fairly rare confluence of rarely occurring constraints and patterns, making it somewhat suboptimal.

On the other hand, we can attempt to extend the duration analysis used for minimal words to stress instead. For instance, we may hypothesize that the first syllable of a word can draw stress if it reaches a particular duration threshold. However, a simple duration account doesn't fully account for the data in Iron. Recall that codas don't have an effect for stress. Even a syllable with complex coda will not bear stress if it has a weak vowel and simplex onset (e.g. /ləʁʒ.ˈɡə.nəɡ/ 'polisher'). Instead, we are forced to conclude that only the duration of pre-vocalic and vocalic segments counts toward the duration threshold for stress. Since onsets only seem to play a role with weak vowels, we must also assume that either the duration of long vowels always meets some minimum threshold that is equal to the length of a complex onset and weak vowel or that duration only matters when the initial syllable has a weak vowel. This seems strange to say the least. If duration affects stress assignment, why only duration in pre-vocalic segments? Segments after the vowel increase the overall duration of the syllable, but do nothing to encourage stress to shift. In contrast, the duration of every segment counts towards the duration threshold for a minimal word (e.g. $\mathrm{v}_{\mathrm{WEAK}}$CC syllables do not draw stress but are acceptable minimal words). Of course, the lack of $\mathrm{V}_{\mathrm{STRONG}}$ words again presents a problem. While $\mathrm{V}_{\mathrm{STRONG}}$ is a stressed initial syllable, it cannot form a minimal word. This suggests that if there is a unified duration analysis, the duration requirements for stress must be much lower than the duration requirements for a minimal word (since $\mathrm{V}_{\mathrm{STRONG}}$ can be stressed, but not be a word).

It also seems unlikely that a unified durational analysis would be completely insensitive to segment type since segments vary in duration. A gradient measure like duration predicts gradient behavior. For example, there is at least one exception to the minimal word duration requirements. The word /χ^{w}ɨ/ 'pig' exists, despite only having two segments. It stands to reason that there should be some examples of complex onsets which do not draw stress because they do not provide enough of a duration boost, or simplex onsets that do draw stress because they are abnormally long. However, to the author's knowledge, this does not occur. All known complex onsets draw stress, while all known simplex onsets do not. This returns us to an analysis in which the number of segments is more important than the contents. Two segments must always provide enough duration to draw stress, while one segment never does. The only way this analysis can work is if the duration of complex onsets and simplex onsets form a bimodal distribution, regardless of composition. Since vowel type also matters, strong vowels should pattern with syllables with complex onsets in the bimodal distribution. Therefore, a thorough acoustic analysis is required to confirm that such a pattern exists. If there is no clear bimodal distribution, it would be difficult to form the categorical distinction that clearly exists in Iron. However, we have notably defaulted to the same categorical pattern. Thus, a duration-based analysis provides no additional explanatory benefits and requires an unlikely system in which only pre-vocalic segments can count for duration and segment type is irrelevant.

In summary, each unified analysis is problematic. A moraic analysis for both minimal words and stress requires a typologically rare trimoraic minimal word and coerces every consonant to be moraic. While this is not impossible, it is certainly not as straightforward as using length to determine the minimal word. A unified duration account requires us to assume that the distribution of duration in syllables perfectly reflects a distribution based on structure. The duration of all complex onsets is equivalent to strong vowels, but no sequence of a simplex onset and weak vowel (which can't draw stress) is as long as a single strong vowel (which always draws stress). If the pattern follows from the structure of a syllable, it does not seem prudent to assume that a gradient measure like duration is responsible for the pattern. Unified analyses produce more questions and stipulative constraints than the split analyses.

Since the data points most directly towards a split analysis, we must consider how uncommon that really is. Iron is not the first language in which word minimality and stress are explained by divergent analyses. Many languages (e.g. Khalkha Mongolian, Buriat, Gurkhali, Paamese, Hupa, Yupik, Chuilla, Wintu, etc.) consider CVV (or CV_{STRONG}) to be a heavy syllable and CV(C) to be light, but have CVC minimal words (Garrett 1999). Additionally, coerced moraic weight cannot be used in several of these cases. For instance, unbounded stress systems (e.g. Huasteco, Aguacateic, Murik, Amele, etc.) with opaque foot structure frequently feature CVX word minimality (Garrett 1999). In these languages, minimal words are necessarily determined without referencing foot structure or stress. Similarly, languages with lexical stress also have minimal word requirements which cannot be easily tied to foot structure (Garrett 1999).

Finally, languages with vowel quality distinctions for stress provide a unique problem for unified analysis of minimal words and stress, especially when attempting to coerce moraic weight (as seen in the analysis of Iron). For instance, languages like Chuvash, Au, Mari, Javanese, Malay, Lushootseed, and Aljuitor determine stress based on vowel quality, but do not utilize weight or foot structure for determining minimal words. In each language, the heavy vowel (which may be the non-high vowel, strong vowel, full vowel, etc.) cannot constitute a word even if (C)V forms a bimoraic foot in longer words.[36] In other words, a heavy syllable cannot constitute a word, while light syllables often do. Garrett (1999) even cites Ossetic (but does not specify Iron or Digor) as a prime example of a language in which there is no connection between minimal words and syllable weight, lending support to a split analysis. It is for these reasons that Garrett (1999) suggests a single constraint that can account for all minimal word sizes, regardless of foot structure or syllable weight. A lack of connection between foot structure or stress and word minima is typologically *more* common than the alternative for languages which are sensitive to vowel type in stress assignment (Garrett 1999). Thus, it is not necessarily problematic to use a separate analysis for minimal words and stress or foot structure. Since there is little to no evidence that the unified accounts have better explanatory power, it seems prudent to use the analyses that best fit the data in each case. Regardless of whether a unified or non-unified analysis is used for minimality, the weight effects of onset complexity are robust.

[36] In fact, Au shows the exact pattern seen in Iron. CV words are allowed only if the V is full, while CVC words are allowed regardless of whether the vowel is full or reduced. Reduced vowels count as light in the stress system (Garrett 1999; Scorza 1985).

9 Discussion

This paper provides conclusive evidence that stress in Iron is sensitive to onset complexity, but not onset presence. To account for this, a new OT constraint is proposed that specifically penalizes moraic simplex onsets. However, utilizing this constraint requires the assumption that it is present in other languages. In other words, other languages should show similar categorical sensitivity to onset or coda complexity in either stress assignment or word minimality. In the introduction, some strong cases of apparent categorical onset complexity sensitivity were shown to be problematic (Bislama and Nankina). However, while those were the most studied cases, they are not the only ones. Gordon (2006) presents a myriad of languages that may exemplify categorical complexity sensitivity in coda or onset position. One such example, Stoney Dakota, claims to be sensitive to coda complexity but not coda presence (Gordon 2006; Shaw 1985). Shaw (1985) indicates that one rule of Stoney Dakota stress, the "Innovative Stoney Stress Rule" is sensitive to coda complexity. Syllables of form (C)VCC are heavy, while (C)VC and (C)V syllables are light (and of equal weight) (Gordon 2006; Shaw 1985). There are additional facts that may complicate this analysis. For instance, at the time of authorship, this was a change in progress and the language also appears to only consider closed syllables heavy (CVV is light despite a long vowel) (Shaw 1985). However, on the surface, it parallels Iron and shows categorical sensitivity to coda complexity.

Other languages are categorically sensitive to onset complexity or coda complexity (but not presence) for minimal words. For instance, minimal words in Czech can take the form CCV but not CV. Similarly, both Kashuyana (CCV & CVCV) and Tsou (CCV & CVV) allow CCV words but disallow CV words. Adopting a minimal prosodic foot approach would indicate that CCV is considered bimoraic in these languages, while CV is monomoraic. This is easily handled with the proposed constraint against moraic simplex onsets ($*\mu|\text{ONS}_{[\text{SIMPLEX}]}$), which would be ranked above the constraint that coerces moraic weight to satisfy word minimality (GRWD=PRWD). Thus, a number of languages appear to have a pattern similar to what is seen in Iron that can be explained by relying on the same constraint. Additionally, it appears that complexity sensitivity can occur for either onset or coda position. That is to say, there is nothing that indicates the constraint $*\mu|\text{CODA[SIMPLEX]}$ does not also exist and generate similar patterns.

Finally, Topintzi (2022) recently argued that Cypriot Greek shows apparent sensitivity to onset complexity, as some complex onsets can count as heavy for the purposes of stress assignment, akin to what is also seen with geminate onsets. In this work, Topintzi (2022) argues that onset complexity weight must necessarily be derived in the surface based on structure and proposes a constraint requiring complex onsets to be moraic. Notably, Cypriot Greek displays gradient behavior where only some complex onsets are considered heavy, which makes the circumstances more complicated. However, the adoption of a this complexity-based constraint by someone historically skeptical of such a system lends support to the use of this constraint.

Of note, the proposed constraint ($*\mu|\text{ONS}_{[\text{SIMPLEX}]}$) does not predict or explain systems where consonants provide additive weight. In fact, it only generates a categorical split between simplex and complex onsets, so onset presence did not play a role. Additionally, there are no levels of complexity. A three consonant cluster in this system would be just as heavy as a two consonant cluster, since only moraic simplex onsets are penalized. This is not what is seen in additive systems. As noted earlier, some languages, like Hindi, appear to exemplify sensitivity to complexity in an additive way (Gordon 2006; Ohala 1977). It is generally assumed that, in Hindi, syllables with a short vowel (V) are light (monomoraic), syllables with a long vowel (V:) or coda (VC) are heavy (bimoraic), and syllables with a long vowel and coda (CV:C) or complex coda are superheavy (CVCC) (trimoraic) (Gordon 2006; Broselow, Chen & Huffman 1997; Ohala 1977; Pandey 2021). In this case, each consonant in coda position appears to be assigned a mora. This type of additive weight is not handled easily by the same system employed in this paper. However, such a system can be handled by other commonly used constraints from the *APPEND series (Rosenthall & Van Der Hulst 1999; Sherer 1994), constraints against mora sharing (NOSHAREMORA) (Broselow et al. 1997), and constraints requiring all coda consonants to be dominated by a mora (MORAICCODA) (Broselow et al.

1997). Essentially, additive weight systems can occur, but are distinct from the complex/simplex system found in Iron. Finally, the use of this constraint does predict a system should occur where there is a divide between simplex and complex onsets, but no divide between types of complex onsets (i.e. CCCV, CCV > CV, V). Identifying a language with this pattern would lend greater support to the proposed constraint and categorical analysis put forth in this paper.

The analysis presented in this paper relies on categorical syllable weight, where some syllable types are defined as light while others are heavy. This weight difference is attributed to moraic structure associated with complex onsets. However, a growing body of work has argued that moraic structure may not be needed to define syllable weight or onset sensitivity, including gradient weight analyses (Ryan 2011, 2014, 2016). In a gradient weight analysis, syllable types are distributed along a continuous weight spectrum. Syllable types at each extreme are associated with either a diminished likelihood (for lighter syllables) or increased likelihood (for heavier syllables) of co-occurring in metrically strong positions (i.e. stressed syllables). In this way, characteristics that increase the prominence of a syllable in some way (such as duration, intensity, or other acoustic features) can be associated with stress effects without introducing moraic structure. Languages with gradient weight often show categorical weight as well. For instance, a language may have categorical vowel weight, but gradient onset weight.

Gradient onset weight has been noted in English (Ryan 2014), Russian (Ryan 2014), and Portuguese (Garcia 2017). Ryan (2011) also argues that gradient onset weight occurs in apparent binary metrical systems (e.g. Kamban's Tamil epic meter, Homeric Greek hexameter, Latin hexameter, Finnish Kalevala meter, Epic Sanskrit meter, and Old Norse poetry). Notably, in Old Norse, Russian, Portuguese, and English, onset complexity is gradiently heavy (Ryan 2011; Garcia 2017; Ryan 2016). Syllables with an onset are statistically more likely to be stressed, and each additional consonant contributes to the statistical likelihood of stress (C < CC < CCC). In addition, mean duration of onsets in Tamil is also significantly correlated with metrical weight (Ryan 2011). Ryan (2014; 2016) has proposed that gradient onset weight can be attributed to *p-center* shifting. The *p-center* can be described as the "perceptual beat of the syllable" (Ryan 2016, pp 727). It approximates where the vowel will occur (the major 'beat') but occurs earlier with longer onsets. Since vowels are the major beat, onsets have a smaller effect on whether a syllable draws stress compared to vowels (Ryan 2016). Of note, languages like Pirahã in which voiceless onsets contribute weight while voiced onsets don't can be characterized by their effects on the *p-center* of a syllable. Voiceless stops generally have a longer duration than voiced stops and may have a stronger effect on the *p-center* of a syllable. Ryan (2014) additionally argues that voiceless onsets in English show a similar gradient effect, where syllables with durationally longer voiceless onsets are more likely to be stressed than the comparatively shorter voiced onsets. Thus a complex onset may similarly have a stronger effect on syllable *p-center* due to its increased duration (Ryan 2014, 2016).

However, this should predict at least a minor effect of a simplex onset in Iron or gradient sensitivity to segment type, which does not occur. In addition, it predicts that certain types of pre-vocalic sequences may have a greater effect on a syllable's *p-center* (Ryan 2014). If the shift in the *p-center* reaches a certain threshold it may draw stress from the second syllable. However, again this predicts that the system would be sensitive to composition of the clusters. For instance, some complex onset may not shift a syllables *p-center* as much and therefore should not draw stress. Conversely, some simplex onsets with strong effects on a syllables *p-center* could draw stress. Since these patterns do not occur, we must conclude that the perceptual benefits are completely categorical and determined by the number of pre-vocalic segments. Two segments always draw stress, while one segment never does so. In contrast, a language like Cypriot Greek (Topintzi 2022) in which some complex onsets are considered heavy and some are not is much more compatible with a *p-center* analysis. Indeed, Topintzi (2022) states that only the less sonorous obstruent-obstruent clusters can form heavy complex onsets in Cypriot Greek, indicating there may be a categorical split based on the gradient *p-center* shifting. Since all complex onsets count as heavy in Iron, a *p-center* account would only be appropriate if all complex onsets provide more *p-center* shifting than their simplex counterparts.

Similarly, Gordon (2005) argues that syllable weight is related to phonetic properties of the syllable and does not rely on moraic weight. Gordon (2005) appeals to auditory adaptation and recovery to explain the greater weight of less sonorous onsets compared to more sonorous onsets. In this analysis, the low intensity segments preceding a high intensity vowel improves the perception of the vowel. Voiceless onsets (which are lower intensity than voiced) thus provide the greatest auditory boost for a following vowel (Gordon 2005). Similarly, a longer onset induces a longer period of relatively low sonority compared to a shorter onset. Future work could evaluate whether complex and simplex onsets display the same split in perceptual energy that is seen between syllables with voiced or voiceless consonants (akin to Gordon (2005) and Gordon (2002)). Gordon (2005) further argues that stress is determined based on prominence constraints that associate certain syllable types with higher or lower prominence based on their acoustic features.

While the data in Iron appears to be clearly categorical, it is potentially compatible with parts of the analyses put forth by Gordon (2002, 2005) and Ryan (2014). Notably, the complex and simplex categorical split for onset weight is only relevant before weak vowels. This is in line with rimal primacy as strong vowels will always be stressed. However, it also means that the onset complexity effects may interplay with the acoustically weak central vowel. It is easy to imagine that weak central vowels would receive a huge auditory perception boost from a complex onset compared to the boost from a null or simplex onset. Gordon (2005) argues that such an effect could be captured by prominence constraints related to the acoustic effects of a simplex vs. complex onsets. Since these constraints are independently ranked, it is feasible that a ranking would allow complex onsets to affect stress without requiring simplex onsets to do so as well.

A gradient analysis also has some explanatory weight in Iron. In fact, Ryan (2011) notes that onset complexity seems to have a lesser statistical effect for syllables already considered heavy compared to those considered light. Thus, the apparent lack of weight difference between syllables with strong vowels and different onset types is predicted by work of this type. However, in these studies, the presence or absence of an onset was more often statistically significant compared to a complex vs. simplex onset (Ryan 2011). This is incompatible with the data in Iron, in which onset presence alone seems to have no effect. Therefore, it seems that any gradient analysis requires some binary distinctions as well. However, this begs for a larger scale corpus analysis of Iron, especially in casual connected speech. Although speculative, this discussion shows that onset complexity sensitivity in Iron is amenable to a non-moraic analysis related to perceptual or acoustic effects, either for the *p-center*, relative prominence of a syllable, or acoustic boosts for following weak vowels. Specifically, the phonetic properties of simplex vs. complex onsets could align with a large perceptual difference. However, the fact that segment type plays no role does give pause. Whatever the analysis, it should also account for other apparent categorical complexity languages discussed in this section including Stoney Dakota, Czech, Kashuyana, Tsou, etc.

As a final note, recall that in Iron coda consonants do not seem to contribute weight in any noticeable way while onsets do. Codas, generally, are much more likely candidates for weight. Therefore, allowing onsets to affect weight implies that codas should also play a role. Since vowel type is most important in dictating stress, we can say that Iron does abide by the typological universal that rimal weight takes precedence over onset weight. However, in this case, rimal weight does not include any coda contribution. Further corpus analyses could confirm that codas in fact play no role (even gradient). If confirmed, this is likely caused by the ability to coerce and penalize onset and coda moraic structure independently ($*\mu_{[\text{ONS}]}$ / $\text{WBP}_{[\text{ONS}]}$ vs $*\mu|\text{CODA}$ / WBP[CODA]). In fact, the existence of separate coda and onset rules (which is necessary for many onset sensitive analyses in work done by Topintzi (2010)) does predict that a system could allow moraic onsets without codas, even if it only rarely occurs. A number of languages do feature onset sensitivity and are insensitive to codas including Arabela (Topintzi 2010), Pattani Malay (Topintzi 2010), Arrernte (Topintzi & Nevins 2017), and Cypriot Greek (Topintzi 2022). This provides evidence that parallel constraints for codas are more common than previously expected. The typological infrequency of onset weight and coda weightlessness should be attributed to other factors, rather than a lack of constraints allowing it to happen.

10 Conclusion

This paper provides a detailed, data-driven analysis of the stress system of Iron. In Iron, heavy syllables include syllables with complex onsets or strong vowels. Syllables that have neither are light. The fact that syllables with simplex onsets are not heavier than syllables with no onsets, but syllables with complex onsets are heavier than those with simplex onsets (i.e. CCV > CV, V) is a challenge for current OT models of stress. This challenge has been addressed by utilizing a constraint that is sensitive to the categorical divide between simplex and complex onsets, which may be motivated by acoustic or perceptual effects on following vowels.

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Amber Lubera
Department of Linguistics
The University of Arizona
Communications Building 114G
Tucson, AZ 85721
allubera@email.arizona.edu