Wıìlıìdeh Yatıì Stress Revisited: Evidence for Iambic Foot Structure

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1. Introduction

Wıìlıìdeh Yatıì, also known as Weledeh, is a dialect of Tłı̨chǫ Yatıì, or Dogrib (Ethnologue: DGR), a Northeast Dene (Athabaskan) language spoken in Canada's Northwest Territories. This paper reports on a phonetic pilot study (~10,000 measurements) of stress correlates and consonant length in this language, to help us better understand the phonological system of the language.

It has long been observed that Dene languages have phonetically long consonants—in particular, stem-initially (Tuttle 2005). However, opinions differ as to whether this lengthening is 'phonological' or not, and, if so, how it should be formally represented (Young & Morgan 1987). How, if at all, geminate consonants should be represented phonologically in Dene languages has profound implications for how we understand syllabification, syllable weight, and the stress system. Here, again, it had been previously assumed that Dene languages have no stress system at all: there are 'stress languages' and 'tone languages', and tone languages were assumed not to have a stress system. However, more recent work has shown that Dene languages do indeed have complex stress systems (Tuttle 1998), and understanding these stress sytems may hold the key to also understanding the otherwise highly comlplex and puzzling morphophonemics of verbs:

> "…an understanding of this structure, the prosodic structure, will provide fresh insight into the basic operation of Athapaskan languages and will ultimately yield an understanding of Athapaskan languages that makes them look less bizarre and more like better understood languages" (Rice 1990: 243).

The phonetic correlates of stress vary considerably across languages. While most languages use some combination of increased duration (length), greater vowel intensity (loudness), and higher pitch (tone) to mark a stressed vowel, these correlates may be used in different combinations or to different degrees, so that when a native speaker of one language pronounces a syllable as stressed, it may or may not sound stressed to a native speaker of a different language. Stated differently, it is possible to mis-judge stress, when listening for it in a language that is not our native language, because we do not necessarily know which cues exactly a native speaker listens for.

In the present case, in my own previous work on Wıìlıìdeh (Jaker 2012), I analyzed Wıìlıìdeh as a moraic trochee system with a Latin-type stress rule—with an additional factor, since Wıìlıìdeh is a tone langauge, that High tone also attracts stress (Tuttle 1998, DeLacy 2002). A Latin-type stress rule means that the penultimate syllable is stressed if it is heavy (having a long vowel, or being closed by a consonant), but if the penultimate syllable is light, then the antepenultimate syllable is stressed. So this analysis predicts, for example, that in a word like *segele* 'they fix things', stress will be on the antepenultimate syllable *se* because *ge* is light, whereas in a word like *yagı̨ı̨htı* 'they were praying', stress will be on the penultimate syllable *gı̨ı̨*, because it is heavy, because it has a long vowel.[1] The claim that High tone attracts stress means that this fairly simple weight-based pattern can be altered depending on where the tones are. Thus, if the stem is preceded by a (High-Low) tone pattern, then we predict a word with antepenultimate stress, as in *k'ewìt'à* *[(ˈk'e.wì)t'a] 'we (2) walk around', whereas if the stem is preceded by a (Low-High) tone pattern, we predict penultimate stress, as in *nàgezè* *[(nà.ˈge)zè]'they hunt'. Finally, in Jaker 2012, I also made a claim about consonant length. The claim was that, given the way moraic trochees and the Latin-type stress rule work, if the penultimate syllable is stressed, then it *must* be heavy. But how can the syllable be heavy if it only has a short vowel? The answer I gave was that you lengthen the initial consonant of the next syllable. So according to this hypothesis, a word like *segele* 'they fix things', the antepenultimate syllable *se* is stressed and the *l* is short *[(ˈse.ge)(ˈle)], while in a word like *sele* 'he/she fixes things', *se* is also stressed, but the *l* is long *[(ˈsel)(ˈle)].[2] The explanation for this supposed pattern is that syllables are grouped into FEET, which we notate with parentheses ( ). In a moraic trochee system there should be two moras in every foot, which means either one heavy syllable (CVC) or (CVV), or two light syllables (CV.CV). Thus the form *segele* is okay the way it is, because the syllables *sege* can form a foot with two moras, but in *sele*, the syllable *se* is not big enough to fill up a foot by itself, which is why the following consonant *l* needs to lengthen, to make the preceding syllable heavier.

As mentioned above, different languages use different phonetic correlates to mark stress, which is why our intuitions about stress can potentially give us the wrong impression, when listening to a language that is not our native language. This is why it is important to do phonetic experiments to learn what is really going on with stress. In the present case, what I found was that, although almost all of the intuitions and patterns described above have some phonetic basis, if we look at the actual phonetic measurements, the data suggest a very different interpretation. Thus I found it is true, for example, that the penultimate syllable in *nàgezè* [(nà.ˈge)(ˈzːè)] 'they hunt' is much more prominent than in *segele* [(se.ge)(ˈlːe)] and this difference can be attributed to different tone patterns in the two words (Low-High-Low) versus (High-High-High). However, in *segele*, it is not the case that the initial syllable *se* is stressed, as the moraic trochee analysis would predict; rather, in both cases, the stem is preceded by an IAMBIC FOOT. In *segele*, what we have is not a trochee, but a STRESSLESS IAMB—a group of two syllables that sound basically flat, with the second syllable slightly more prominent—which is different from both a stressed iamb and a stressed trochee. In a similar way, while there is a difference in consonant length in words like *sele* versus *segele*, in both cases, the *l* is long enough to count as phonologically 'long' or 'geminate'. There is still an explanation for the consonant length difference, but under a very different analysis: Wıìlıìdeh is an iambic system, which means that syllables are grouped together into groups with a (weak-strong) pattern. In this system, consonants tend to be longer foot-medially than foot-initially, a pattern we will explain in sections 3 and 4 below.

[1] I assume that the *h* classifier does not count for weight, and is syllabified together with the stem. That the classifier has a special prosodic status has been proposed previously in the literature (McDonough 1990, Hargus & Tuttle 1997).

[2] These phonetic transcriptions are marked with an asterisk, because, as we shall see shortly, these are not the correct stress patterns for these words.

2. Experiment

This experiment was originally designed based on the moraic trochee hypothesis described above, combined with the Latin stress rule. Very early on, in analyzing the measurements, it became apparent that this original hypothesis was incorrect, and that the data were instead suggestive of an iambic system. Because of this, I then proceeded to try and re-analyze the data in terms of an iambic system, and the categories which are predicted to exist under such a system. As a result, from the point of view of the new analysis, there are gaps and irregularities in the data. For example, absent from the data set are 3-syllable words with a (High-Low-High) or (High-Low-Low) tone pattern. Under the new hypothesis, words of this type would be very important. For example, a word like *k'ewìt'à* [(ˈk'e.wì)(ˈtː'a)] 'we (2) are walking around' would be one of the few words with a genuinely trochaic stress pattern, since the (High-Low) sequence before the stem would attract stress onto the antepenultimate syllable *k'e*. However, under the previous moraic trochee hypothesis, I had considered including such words unnecessary, since they were predicted to have the same stress pattern as *segele* [(se.ge)(ˈlːe)] (which, as it turns out, they don't). There are also differences in the numbers of tokens various categories for similar reasons. A summary chart of the different predictions of the two models—the moraic trochee with Latin stress rule, or the iambic analysis—is given in (1). For both analyses, I assume that High tone attracts stress.

(1) Different predictions of moraic trochee vs. iambic hypotheses

Syllable count and tone pattern	**Moraic trochee + Latin stress rule**	**Iambs**
a. 2 syll, (High-High)	penultimate stress *(ˈk'eg)ge	final stress (k'e.ˈgːe) *'he/she carries a baby'*
b. 2 syll, (High-Low)	penultimate stress *(ˈdet)t'è	penultimate stress (ˈde.tː'è) *'he/she starts cooking'*
c. 2 syll, (Low-High)	final stress *(ʃè.tį)	final stress (ʃè.ˈtːį) *'he/she is eating'*
d. 2 syll, (Low-Low)	penultimate stress *(ˈnàz)zè	final stress (nà.ˈzːè) *'he/she is hunting'*
e. 3 syll, (High-High-High)	antepenultimate stress *(ˈse.ge)le	stressless iamb (se.ge)(ˈlːe) *'they are fixing things'*
f. 3 syll, (High-High-Low)	antepenultimate stress *(ˈʔe.de)ts'ò	stressless iamb (?) (ʔe.de)(ˈtːs'ò) *'he is scratching himself'*
g. 3 syll, (Low-High-High)	penultimate stress *(ʃè.ˈge)tį	penultimate stress (ʃè.ˈge)(ˈtːį) *'they (2) are eating'*

h. 3 syll, (Low-High-Low)	penultimate stress *(nà.ˈge)zè	penultimate stress (nà.ˈge)(ˈzːè) *'they are hunting'*

To anticipate my conclusion, all of the words in the moraic trochee column are marked with an asterisk (*), to indicate that these are not in fact the correct parse. Even in cases where the moraic trochee and iambic analysis make superficially similar predictions, they differ in their predictions about whether the stem-initial consonant is geminate, for example, and whether the stem syllable is stressed or extrametrical. The only place where the iambic analysis seems to make an incorrect prediction is (1)(f), in words such as *ʔedets'ò* 'he scratched himself'. Here the iambic analysis (Jaker & Kiparsky, to appear) predicts a stressless iamb, whereas the experimental results seem to suggest a stressed iamb. However, the number of tokens was very small for this category, and additional data will be necessary to determine the correct parse for words with (High-High-Low) tone patterns.

2.1 Experimental design

This experiment measured data from both 2-syllable and 3-syllable words, and took two sets of measurements from the same sets of words: measurements of stress correlates on the vowels (duration, amplitude, and F0), and length measurements on the consonants. We will discuss each of these in turn.

The stimuli consisted of both 2-syllable and 3-syllable words with different tone patterns. For 2-syllable words, I investigated all four logically possible tone patterns: (High-High), (High-Low), (Low-High), and (High-Low). The 3-syllable words also consisted of four different tone patterns: (High-High-High), (High-High-Low), (Low-High-High), and (Low-High-Low). That is, not included in the stimulus set were words where the penultimate syllable was Low. In retrospect, given the iambic hypothesis, these would have been important stimuli to include, as we would predict them to be exceptional, and actually exhibit a trochaic stress pattern, when the tone pattern before the stem was (High-Low). However, under the moraic trochee hypothesis, instances of trochaic feet were already included, whenever there was either a (High-High) pattern before the stem, which is why (High-Low) tone patterns were not included in the original design.

We now turn to which factors were controlled for and not controlled for in the experiment design. Wıìlıìdeh has contrastive vowel length, meaning that there are both long and short vowels—the long vowels being what we write with a double vowel in the orthography. For example *gejı̨* [(ge.ˈdːʒį)] is 'they are singing', while *geejı̨* [(ˈgeː)(ˈdːʒį) means 'they are afraid'. Short vowels allow for two contrastive tones, High tone Low, where the Low tone is written with a Low tone mark (à, è, ì, ò). On long vowels, there are four contrastive tones: High, Low, Rising, and Falling. For example, the word *nìıtła* means 'he/she will arrive', while *nıìtła* means 'he/she gets up'. Based on cross-linguistic studies, we expect that languages will mark stress mainly using phonetic correlates that are not contrastive in the language already (Flemming 1996, 2001). In this case, since duration is already contrastive in the language (to mark long vowels) and F0 is already contrastive (to distinguish four different tones), we expect that the primary and most reliable cue for stress in Wıìlıìdeh will be intensity. This does not mean that the other correlates will not be used at all, only that we expect them to be used to a lesser degree. That is, we expect that a vowel with Low tone which is stressed will have a slightly higher pitch, but not so high as to be confused with a High tone. Similarly, a short vowel which is stressed will have a slightly longer duration, but not so much as to be confused with a long vowel.

To control for these factors, I first selected only words which had all short vowels, as part of the experiment design (in running the experiment, sometimes speakers did produce words with a long vowel which was unexpected, and these words were coded separately). This also means that contour tones were excluded in principle: all of the tones were either High or Low. The words measured were all verbs taken from my *Weledeh Verb Dictionary*. In most cases, I chose verbs which were two syllables long in the 3rd person singular form, such as *sele* [(se.ˈlːe)] 'he/she is fixing things', *k'ege* [(k'e.ˈgːe)] 'he/she is carrying a baby', *nàzè* [(nà.ˈzːè)] 'he/she is hunting', etc., and derived the 3-syllable token from these by using the 3rd person plural form with *ge*, i.e. *segele* [(se.ge)(ˈlːe)] 'they are fixing things', *k'egege* [(k'e.ge)(ˈgːe)] 'they are carrying a baby', *nàgezè* [(nà.ˈge)(ˈzːe)] 'they are hunting'. I also sometimes included the impersonal form with *ts'e*, as in *sets'ele* 'we fix things', based on the same procedure. Thus, lexical tone and vowel length were controlled for in the manner described above. Morphology was also controlled for, to the extent that the final syllable of every word was also the stem. Other factors, such as whether or not a disjunct prefix was present, whether an *l*-classifier was present underlyingly, and whether the penultimate vowel was underlying or epenthetic were also coded for in the original data spreadsheet, but these other factors turned out to have no effect.

One other factor which is potentially relevant, but which was not entirely controlled for, was vowel quality. Historically, all Dene languages once had a distinction between FULL and REDUCED vowels, where the full vowels were long and tense, and the reduced vowels were short, lax, and centralized—that is, *aː, eː, iː,* and *uː* for the full vowels, and *ʌ*, *ə*, and *ʊ* for the reduced vowels. It is implicitly assumed by most linguists that the full ~ reduced vowel contrast has been lost in most Northeast Dene languages, at least in prefixes (Ackroyd 1982, Rice 1989, Cook 2004; though see Krauss 1983 for a contrary view for Dëne Sųłıné). In this paper I will follow the majority view in assuming that the full ~ reduced vowel contrast is no longer maintained in Wıılıìdeh: all single vowels are short, and all double vowels are long (where the double vowels arise, historically, from a consonant deleting in between two vowels). However, I will note that in the 3-syllable words described above, where the penultimate syllable is either *ge* or *ts'e*, the vowel of the penultimate syllable always comes from a reduced vowel historically. In these same examples, the antepenultimate syllable is always a disjunct prefix with the vowel *a* or *e*, which in these cases comes from either of the full vowels *aː* or *eː* historically. Therefore, in so far as the full ~ reduced contrast is still relevant at all, we would expect it to introduce a slight bias towards longer duration on the antepenultimate syllable, in these examples. The fact that, as we shall see, the durational effect goes in the opposite direction is evidence either that the full ~ reduced vowel contrast is no longer present, or that this contrast is overridden by the iambic stress pattern of the language.

2.2 Procedure

I recorded three subjects, all middle-aged, fluent speakers of Wıılıìdeh, and also fluent in English, using a Marantz PMD-671 digital recorder and unidirectional condenser microphone. Subjects were shown a series of powerpoint slides containing questions with the stimulus embedded in a carrier sentence, and asked to respond with the sentence "*heʔę, _________ nǫ̀ǫ̀*" or *"yes* ***[verb***

phrase] *it seems".* The stimulus words were all verb forms, as described above, 2 or 3 syllables long, with syllables containing only short vowels, and all syllables of the chape CV.

For vowel stress correlates, I took 7 measurements for each vowel in the word: duration, Mean F0, Max F0, Min F0, Mean intensity, and Max intensity. For consonants, I took 3 measurements for each consonant: closure duration, release duration, and total duration (closure + release). For sonorants, I assumed that there is no release, thus closure duration = total duration. For aspirate stops, given that aspiration in Dene languages is often accompanied by a great deal of frication noise (McDonough & Wood 2008), I included the aspiration and VOT as part of the consonant duration, rather than as part of the following vowel.

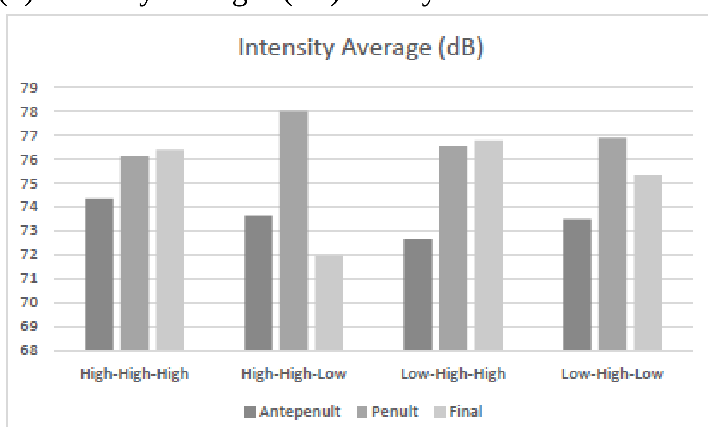
2.3 Results

In this section, I will summarize the results, first for stress correlates, and then for consonant duration.

2.3.1 Stress correlates

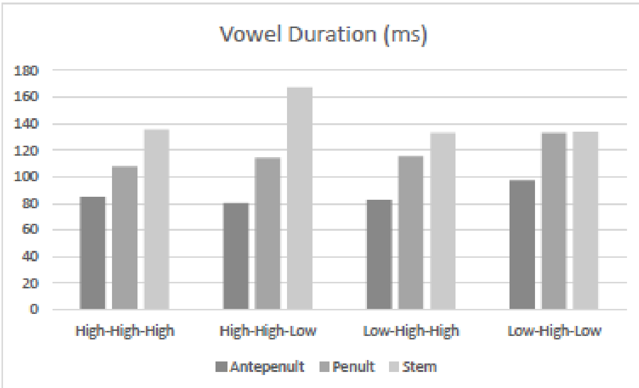
As mentioned in 2.1, because Wıılıìdeh is a language in which both vowel length and tone are contrastive, we would expect intensity to be the main cue to stress, under Dispersion Theory (Flemming 1996, 2001). That being the case, under the moraic trochee hypothesis, we would expect the antepenultimate vowel to have greater intensity than the penultimate vowel whenever there is a (High-High) sequence preceding the stem, and, conversely, we would expect the penultimate vowel to have greater intensity than the antepenultimate vowel where there is a (Low-High) sequence before the stem. Instead, what we see in (1) is that, in all four tone patterns investigated, the penultimate vowel has greater intensity—albiet to differing degrees. This difference was almost always statistically significant, even with a relatively small number of tokens. Thus, in (High-High-High) sequences, the penultimate syllable has greater intensity than the antepenultimate ($p < .001$, $n = 35$, equal variances). A similar trend is found in (High-High-Low) sequences; it is likely that this trend would become significant with a larger number of tokens ($p = .069$, $n = 4$, equal variances). This difference in intensity was also significant in (Low-High-High) sequences ($p < .001$, $n = 15$, equal variances) and (Low-High-Low) sequences ($p < .001$, $n = 25$, equal variances).

(1) Intensity averages (dB) in 3-syllable words



The same trends were visible with all 7 stress measurements, and, in most cases, the difference between the antepenultimate and penultimate syllables was statistically significant. To further illustrate, consider vowel duration, as shown in (2).

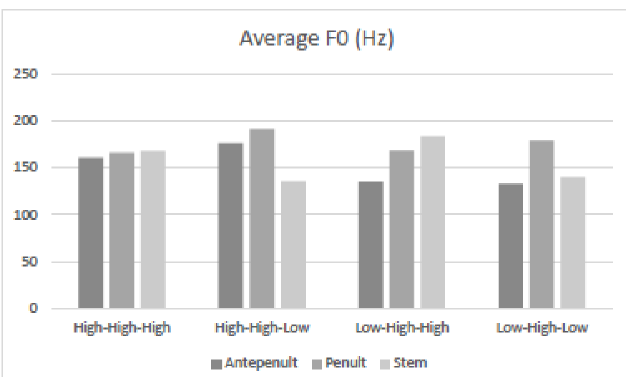
(2) Vowel duration (ms) in 3-syllable words



As shown in (2), with all tone patterns, vowel duration showed a steadily increasing pattern across all three syllables, though again to varying degrees. Recall that all of the vowels in question are lexically short, and, historically, the antepenultimate vowels were full, while the penultimate vowels were reduced. Therefore, the difference in duration between the antepenultimate and penultimate vowels must be due to the stress pattern. In all cases, the difference was statistically significant: in (High-High-High) sequences ($p < .001$, $n = 35$, equal variances); in (High-High-Low) sequences ($p = .021$, $n = 4$, equal variances); in (Low-High-High) sequences ($p < .001$, $n = 15$, equal variances); and in (Low-High-Low) sequences ($p < .001$, $n = 25$, equal variances).

Finally, we come to the measurement of tone itself, as shown in (3).

(3) Average F0 (Hz) in 3-syllable words



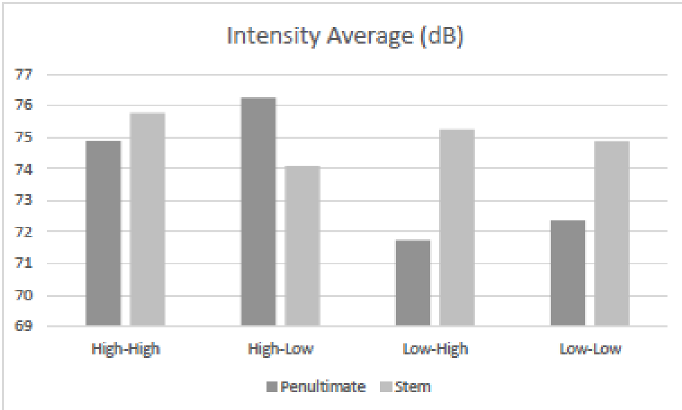
While it is of course to be expected that a vowel with lexical High tone will have a higher F0 than a vowel with Low tone, what is interesting in (3) is that, in (High-High) sequences preceding the stem, the High tone on the penultimate syllable is phonetically higher than the High tone on the antepenultimate. In (High-High-High) sequences, this effect was statistically significant ($p < .001$, $n= 35$, paired). The effect was not statistically significant in (High-High-Low) sequences ($p = .304$, $n =4$, paired), but this was most likely due to the very small number of tokens. That is, in (High-High-High) sequences, the effect on F0 was small, with the penultimate vowel only 5.6 Hz higher than the antepenultimate, on average. Yet, this effect was remarkably consistent across all tokens, and thus highly significant. It is difficult to imagine how such an effect could arise in a moraic trochee system, where the antepenultimate syllable was stressed in these examples. However, such an effect makes sense in an iambic system, where the penultimate syllable is stressed, and higher F0 is a phonetic correlate of stress.

We now turn to the phonetic correlates of stress in 2-syllable words. In Jaker 2012, I predicted that stress in 2-syllable words would be, in part, dependent upon what the stem-initial consonant was. This is because, according to the Latin stress rule, in 2-syllable words, normally the penultimate syllable is stressed and heavy, and the final syllable extrametrical. So this analysis predicts that, in 2-syllable words like *sele* 'he/she fixes things', stress will be on the penultimate syllable *se*, and the consonant *l* will be long, in order to make the first syllable heavy. However, in Jaker 2012 I also claimed that some consonants were 'ungeminable', meaning that they could not be phonologically lengthened. These included all aspirate consonants, such as *k, t, tł, ts,* and *ch*, as well as consonants with a very complex articulation, such as *tł'*. So this analysis predicted that words such as *datło* 'he/she is dancing', *etse* 'he/she is crying' and *whetį* 'he/she is sleeping' will have final stress, while words such as *sele* 'he/she fixes things', *k'eda* 'he/she is walking', and *k'ege* 'he/she is carrying a baby' will have penultimate stress. For this reason, all of the stimuli were originally coded as to whether the stem-initial consonant was 'geminable' or 'ungeminable', as well as for other factors, such as whether or not the *l*-classifier was present underlyingly, whether the *whe* conjugation marker was present, and whether the penultimate vowel was underlying or epenthetic.

As it turned out, none of these other factors played any role in stress assignment. The only factor relevant to stress placement, as we shall see below, is the tone pattern: (High-High), (Low-High), and (Low-Low) sequences have final stress (thus following an iambic pattern), while (High-Low) sequences have penultimate stress (thus following a trochaic pattern). For this reason, I reorganized the data, and grouped the tokens only according to stress pattern, for the purpose of stress measurement, as we will see below.

We will begin with measurements of intensity, as shown in (4).

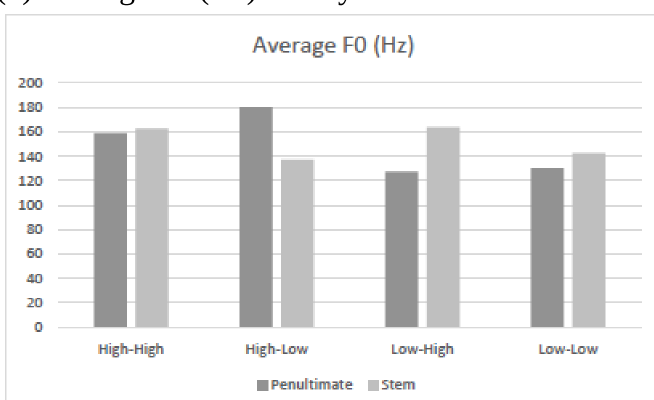
(4) Intensity averages (dB) in 2-syllable words



In all four cases, the difference in intensity was highly significant, $p < .0001$, for a paired t-test: in (High-High) sequences ($n = 127$); in (High-Low) sequences ($n = 65$); in (Low-High) sequences ($n = 14$); and in (Low-Low) sequences ($n = 35$). The same results were also all significant, $p < .001$, using a non-paired t-test assuming equal variances. These results indicate that, in 2-syllable words, stress is by default on the final syllable (the stem), unless there is a (High-Low) tone pattern, in which case stress is attracted onto the penultimate syllable.

The results for vowel duration and pitch have less direct bearing on the question of stress in 2-syllable words, but will be included here for completeness.

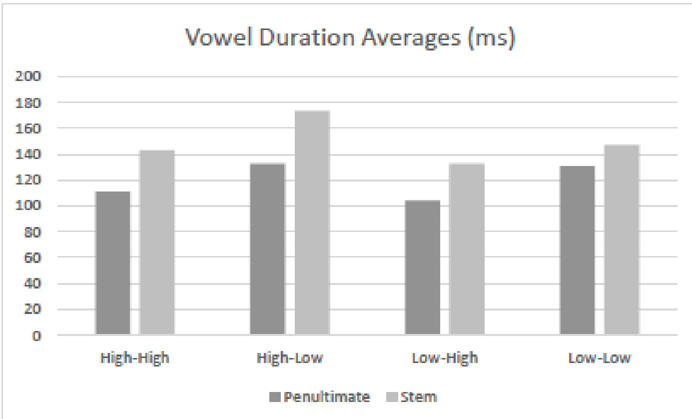
(5) Average F0 (Hz) in 2-syllable words



In (5), all of the differences in F0 shown were statistically significant, for all four tone patterns ($p < .001$, paired). In (High-Low) and (Low-High) sequences, the difference in F0 shown is mainly a correlate of the lexical tone contrast between High and Low tone. That is, it does not seem possible to tease apart, based on the current data set, the effect of stress on F0 from the effect of realization of High tone itself. However, in both (High-High) and (Low-Low) sequences, we find that the final syllable—the stem syllable—is slightly higher in pitch than the penultimate syllable. Since the underlying lexical tones are identical in these sequences, the differences in F0 are most likely a phonetic correlate of stress, providing evidence for stress on the final syllable.

Finally, we will examine vowel duration in 2-syllable words, as shown in (6).

(6) Vowel duration (ms) in 2-syllable words

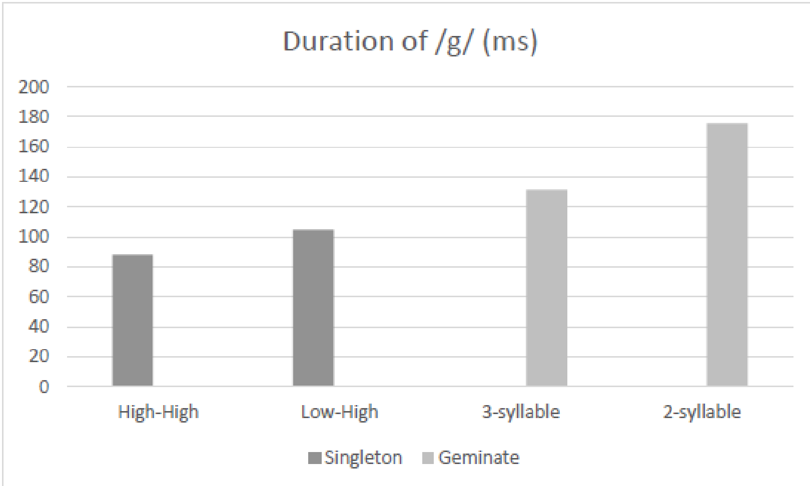


In (6), once again, all of the durational differences shown are statistically significant. However, in this case, all of the effects go in the same direction: the stem vowel is always longer than the penultimate vowel, even in (High-Low) sequences where, so it would otherwise seem, the penultimate syllable is stressed. Most likely this reflects a stem minimality effect: the stem syllable must be of a certain minimal size, and the stem vowel is phonetically lengthened to fill out that size (see section 3).

2.3.2 Consonant duration

Regarding consonant length, there is evidence for a phonological singleton ~ geminate distinction, in that geminate consonants were between 1.52 and 1.66 times the length of singletons ($p < .001$), which is within the range of what is observed for geminate/singleton duration ratios cross-linguistically (Aoyama & Reid 2006). What I mean by 'phonological distinction' will be explained in section 4; briefly, this means that a geminate consonant bears a mora, while a singleton consonant does not. The singleton ~ geminate contrast is best illustrated by the consonant /g/, since this occurs most frequently in the data set. The relevant length measurements are shown in (7).

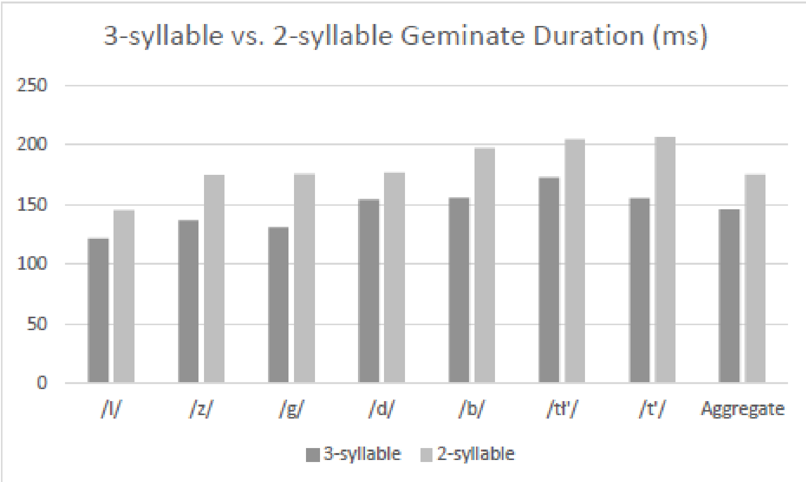
(7) Duration measurements (ms) for /g/



In the case of the consonant *g*, the measurements can be divided into two main groups, which I have labeled 'singleton' and 'geminate'. All of the singleton measurements come from *g* in the onset of the penultimate syllable, as part of the plural marker *ge*, while all of the geminate measurements come from the onset of the stem syllable, in words such as *k'ege* 'he/she is carrying a baby' or *k'egege* 'they are carrying a baby'. Recall that the moraic trochee hypothesis (Jaker 2012) predicted that the consonant *g* should be geminate stem-initially in 2-syllable words like *k'ege*, and singleton stem-initially in 3-syllable words like *k'egege*. Strictly speaking, this hypothesis is false: the sole factor which determines singleton vs. geminate phonological status is whether *g* is in the onset of the stem syllable, or the penultimate syllable: in the former environment it is always geminate, and in the latter, non-geminate. However, there are statistically significant differences within each group. In the case of geminate, stem-initial *g*, *g* is approximately 34% longer in 2-syllable words such as *k'ege*, compared to 3-syllable words such as *k'egege*, a difference which is statistically significant ($p < .016$, $n = 8$, unequal variance). A similar pattern held with *g* in penultimate position: *g* was approximately 19% longer in (Low-High) tone sequences, such as in *nàgezè* 'they are hunting', than in (High-High) tone sequences such as *k'egege*. In both cases, it is likely that these differences in duration are related to prosodic structure. In the case of singleton *g*, the syllable *ge* is stressed more strongly in (Low-High) than in (High-High) sequences, which accounts for the difference in duration.

Regarding the differences in duration among stem-initial, geminate consonants, this effect seems to hold throughout the entire consonant inventory: geminate consonants are approximately 20% longer in 2-syllable words than in 3-syllable words, and the effect is statistically significant ($p < .001$, $n = 73$ 3-syllable words, $n = 129$ 2-syllable words, t-test assuming unequal variances).

(8) Duration of stem-initial geminates in 3-syllable and 2-syllable words



The effect on stem-initial consonant duration is consistent both within and across different stem-initial consonants, and statistically significant. This durational effect is most likely connected to prosodic structure in some way—but how?

3. Discussion

It should be apparent, at this point, that the moraic trochee hypothesis, with Latin stress rule, is not a good fit for the Wıìlıìdeh data presented here. In the case of 2-syllable words, the moraic trochee analysis predicteded that stress should be on the penultimate syllable by default, except in (Low-High) sequences. However, again what we find is the reverse pattern. Stress is on the final syllable (the stem) in (High-High), (Low-Low), and (Low-High) sequences, and only falls on the penultimate syllable in (High-Low) sequences, where High tone shifts stress onto the penultimate. It is true that the moraic trochee analysis could be supplemented by an additional constraint, such as STEMSTRESS, which would introduce a bias towards final stress in 2-syllable words, where the final syllable is the stem. However, in that case, the moraic trochee itself would play no active role in stress assignment, with stress instead being assigned simply by the combination of tone pattern and morphology (we will return to this question in the conclusion). On the other hand, the same results are perfectly consistent with an iambic analysis, even without saying that stress is attracted to stems.

It is really in the case of 3-syllable words, however, where the moraic trochee hypothesis (with Latin stress rule) runs into difficulties. There does not seem to be any reason why, in (High-High-High) sequences, the second syllable (the penultimate) should have greater intensity, greater duration, and Higher F0 than the first syllable (the antepenultimate). What we observe for (High-High-High) sequences in (1)-(3) is a pattern of increasing intensity, duration, and F0 across all three syllables. The question is, why should this be? Even if we do not admit the existence of feet, there is a natural tendency for stresses to alternate (Gordon 2002), which ought to introduce a bias towards greater intensity on the antepenultimate, to avoid stress clash with the stem—instead, the opposite effect is found. Furthermore, from a historical perspective, in most of my tokens, the antepenultimate syllable comes from a full vowel, while in all tokens the penultimate comes from a reduced vowel. This factor, if relevant, would introduce a bias towards greater duration of the antepenultimate compared to the penult, yet here again, the effect goes in the opposite direction. It is difficult to see how such results could be explained under a moraic trochee analysis—at least of the type discussed here.

In the case of consonant length, there was some basis to my intuition (Jaker 2012) that certain stem-initial consonants are longer in 2-syllable words than in 3-syllable words—indeed, this seems to be true across-the-board, for all consonants. However, while the stem-initial consonant in *k'egege,* for example, is shorter than in *k'ege*, in both cases the stem-initial *g* falls into the geminate class. This particular pattern of durational differences is in fact puzzling under both a moraic trochee as well as an iambic analysis, under standard assumptions. For example, in an iambic system, what advantage is there to lengthening the stem-initial *g* in *k'ege,* i.e. (k'eg.ˈge)? In doing so, it appears that we have transformed an otherwise (Light-Light) iamb into a (Heavy-Light) iamb, making the foot less harmonic, and violating the Weight-to-Stress Principle (WSP) (Prince 1990, 1991). As we saw in (7), while stem-initial *g* is about 20% longer in 2-syllable words compared to 3-syllable words, a similar durational difference is found when *g* is in the onset of the penultimate syllable, when comparing (High-High) sequences preceding the stem (where it is shorter) to (Low-High) sequences (where it is longer). Ideally, there ought to be a unified explanation for this durational difference in the onset consonants of both the stem syllable and the penultimate syllable. In the next section, I will propose such an explanation: geminate consonants add onset weight rather than coda weight, and the foot inventory of Wıìlıìdeh includes three types of disyllabic feet: stressed iambs, stressless iambs, and trochees.

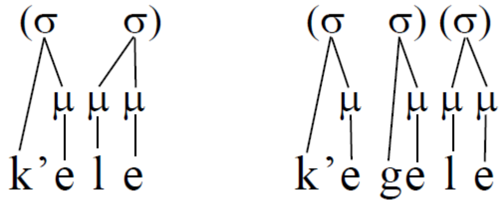
4. New hypothesis: Iambic foot structure and moraic onset geminates

In this section, I will present a new interpretation of the Wıìlıìdeh facts, which has two parts. First, I will argue that the long stem-initial consonants we observe are indeed phonologically geminate, in the sense of bearing a mora, but actually contribute *onset weight* to the following syllable, rather than coda weight to the preceding syllable, and the differences in length which we observe between 2-syllable and 3-syllable words are the result of different positioning of foot boundaries. Second, I will argue that Wıìlıìdeh has an inventory of three types of disyllabic feet: stressed iambs, stressless iambs, and trochees, and that a phonological distinction between stressed and stressless feet explains the consonant length difference we observe for *g* in penultimate position.

4.1 Moraic onset geminates

In the phonology literature, it has been widely assumed that wherever there are phonologically long consonants, i.e. geminates, they always straddle the boundary between two syllables: a geminate *t* such as Italian *fatto* [fatːo] functions both as a coda for the preceding syllable, and an onset to the following syllable. It is also assumed that geminate consonants always add weight to the coda of the preceding syllable, and never to the onset of the following syllable (Hayes 1989). However, there is a growing body of evidence that this is not necessarily the case, and there can be moraic onset geminates (Topintzi 2008, 2010). In the case of Wıìlıìdeh, the representations I propose for moraic onset geminates are illustrated in (9), using the words *k'ele* 'he/she is carrying plural objects around' and *k'egele* 'they are carrying plural objects around'.

(9) Representation of moraic onset geminates



In (9), both word forms consist entirely of iambic feet. (k’e.ˈlːe) is a (Light-Heavy) iambic foot, while the form (k’e.ge)(ˈlːe) consists of a (Light-Light) iambic foot followed by a monosyllabic (Heavy) foot—all three of these foot types are widely considered to be canonical iambic feet (Hayes 1995). Now briefly consider the alternative hypothesis, if these forms were to be re-analyzed with geminates contributing coda weight to the preceding syllable. Since, as we have established in (4), disyllabic (High-High) words have final stress, and are therefore iambs, the form *(k’el.ˈle) would be a highly disharmonic (Heavy-Light) iamb. The form *(k’e.ˈgel)(ˈle) would contain a (Light-Heavy) iamb, which is harmonic, but also a degenerate foot (ˈle). Under the moraic onset analysis, however, the Wıìlıìdeh facts are entirely consistent with what we know about syllable weight patterns in iambic systems.

What about the phonetic length difference, whereby the geminate *l* is approximately 20% longer in *k’ele* than in *k’egele*? As we can see in (9), in both cases, *l* is phonologically geminate, a moraic onset, and occurs in the strong position of an iambic foot. The difference, however, is that in *k’ele*, the geminate occurs foot-medially, while in *k’egele*, it occurs foot-initially. That is, geminate consonants are longer foot medially than they are at foot boundaries. At first, this may seem quite counterintuitive, especially to an English speaker. This is because English is a trochaic language, and in trochaic langauges generally, consonants are weaker foot-medially than at foot boundaries (as in, for example, the English flapping rule, which only occurs foot-medially). However, the opposite pattern is known to occur in iambic languages: consonants are weaker at foot boundaries, and stronger foot-medially (González 2003), as seems to be the case here.[3]

4.2 Stressed and stressless feet

It has also been widely assumed in the phonology literature that every foot must have a stress syllable. However, in more recent work, it has also been argued that it is possible for some feet to be stressless (Hyde 2002, 2003, 2016). That is, this line of research makes a representational distinction between gridmarks and positions: every foot has one and only one strong position, but the strong position may or may not bear a foot-level gridmark. Based on these assumptions, the foot inventory I propose for Wıìlıìdeh is summarized in (10).

[3] The Uralic language Nganasan, which has consonant gradation, uses the strong grade of consonants foot-medially, and the weak grade foot-initially (Vaysman 2002). However, Vaysman assumes that the feet in question are trochaic (2002: 334).

(10) Proposed foot inventory for Wıılıìdeh

stressed iamb	**stressless iamb**	**stressed trochee**	**monosyllabic foot**
$\overset{*}{(\sigma_W\ \sigma_s)}$	$(\sigma_W\ \sigma_s)$	$\overset{*}{(\sigma_s\ \sigma_W)}$	$\overset{*}{(\sigma_s)}$

Under this model, feet have strong and weak positions, notated by the subscripts ‘s’ and ‘w’, and the ‘s’ position may or not bear a gridmark. Phonetically, these different types of feet may be interpreted as follows. The gridmark corresponds to an actual strong, audible stress, as we find for example in trochaic feet such as *det’è* [(ˈde.t’è)]‘he/she starts cooking’, or iambic feet such as *shètı̨* [(ʃe.ˈtį)] ‘he/she is eating’. These stress patterns manifest themselves phonetically as a very sharp fall or rise in intensity between the two vowels. In the case of disyllabic patterns just mentioned, (High-Low) sequences exhibit an average drop in intensity of 2.14dB, while (Low-High) sequences exhibit a rise in intensity of 3.51dB. On the other hand, when a foot only has strong and weak positions, but no gridmark is present, the phonetic correlates of stress are more subtle. Thus, for 3-syllable words, in (High-High-High) sequences, the first two syllables form a stressless iamb (e.g. words like *k’egege* and *segele*). In these words, there is an average increase in intensity of 1.77dB between the first two vowels, and an increase in duration of 22.8ms. On the other hand, in (Low-High-High) sequences, the first two syllables form a stressed iamb (e.g. words like *shègetı̨* ‘they (2) eat’ and *xàgele* ‘they pull things out’). In these words, there is an average increase in intensity of 3.87dB, and an increase in duration of 32.9ms. In other words, compared to stressless iambs, stressed iambs exhibit approximately 1.5 times greater increase in duration between the two vowels, and over 2 times greater increase in intensity. If we also compare the stressless iamb with the stressed trochee (in this case, 2-syllable words with the (High-Low) tone pattern), we can see that the stressless iamb constitutes its own distinct, third foot type, as summarized in the table in (11).

(11) Summary of Δ_{avg} values from 3 foot types

	Δ_{avg} intensity	Δ_{avg} duration
Stressed iamb	3.87dB	32.9ms
Stressless iamb	1.77dB	22.8ms
Trochee	-2.14dB	40.6ms

The duration data for the trochees is somewhat anomalous, since, in so far as duration is a stress correlate, we would expect these feet to exhibit a decrease in duration between the two syllables, rather than an increase of over 40ms. The increase in duration observed in these feet could be due either to the fact that the second syllable in these feet is the final syllable, and thus subject to word-final phonetic lengthening, or that it is the stem syllable, and subject to a stem minimality requirement. I believe it is likely that if we had 3-syllable words with either a (High-Low-High) or (High-Low-Low) tone pattern, for example *k’ewìt’à* [(ˈk’e.wì)(ˈtː’à)] ‘we (2) walk around’, they would show greater duration on the antepenultimate vowel compared with the penultimate. It will therefore be very important to include such words in a future study.

For myself, as a native Italian speaker, the difference between the two different iambic foot types—stressed and unstressed—was very clearly audible; however, as a phonologist assuming that there are only two types of feet, iambs and trochees, I came to the erroneous conclusion that the stressless iambs were actually trochees. However, as the data in this paper help demonstrate, these stressless feet, as we find in (High-High-High) sequences, are clearly iambs, in that the 2nd syllable exhibits greater intensity, duration, and F0 than the first syllable; it is just that this effect is more subtle than in stressed iambs. The most likely phonological explanation for the existence of such feet is that what would otherwise be stressed iambs are de-stressed in certain environments, in order to avoid stress clash (Jaker & Kiparsky, to appear). This difference between two different types of iambic feet is also the most likely explanation for the difference in duration between singleton *g* in different tone sequences which we saw in (7): when *g* occurs in the middle of a (Low-High) tone sequence, it is also part of a stressed iamb, and in the onset of a stressed syllable, where it undergoes fortition, and is phonetically about 20% longer; in (High-High) sequences, *g* occurs in a stressless iamb and is thus in the onset of an unstressed syllable, such that this phonetic lengthening does not occur.

5. Conclusion

I think there are two main methodological lessons I have learned from this study. The first is that the same phonetic cue can be used for very different purposes in different languages. For myself as a native Italian speaker, I am very good at perceiving subtle differences in consonant duration—indeed, my intuition that stem-initial consonants were longer in 2-syllable words than in 3-syllable words turned out to be accurate, as we saw in (8). However, the perceptual threshold for singleton vs. geminate is evidently different in Italian than in Wıìlıìdeh: in Wıìlıìdeh, *all* of the stem-initial consonants are phonologically geminate; the length difference in this case is phonetic only, marking the location of foot boundaries. Along the same lines, in my language, geminate consonants always add weight to the preceding syllable, and are thus often a cue to the preceding syllable being stressed; in Wıìlıìdeh, on the other hand, they add weight to the following syllable, and are a cue that the following syllable is stressed. Thus misinterpreting the role of consonant length caused me to mis-hear the location of stress, in a number of cases.

The second lesson I have learned, related to the first, is to be open to discover new phonological categories, even if these have been claimed to be impossible. In this case, I had been trained to believe that both moraic onset geminates as well as stressless feet were impossible in principle. In the case of geminates, this assumption led me to make incorrect assumtions about syllable weight. In the case of stressless feet, hearing a contrast between two different types of feet in (High-High-High) versus (Low-High-High) sequences, and believing that there were only two different possible types of feet (iambs or trochees, both with a stressed syllable), I was erroneously led to assume that in words like *segele* [(se.ge)(ˈlːe)] ‘they fix plural objects’, stress was on the initial syllable. This led me into a number of complications, and left many facts unaccounted for. On the other hand, once we allow for moraic onset geminates and stressless feet, it seems that all of the observable phonetic facts are explained, and the phonological analysis of the system is greatly ‘cleaned up’ and simplified (Jaker & Kiparsky, to appear).

While I believe this study has shown that the moraic trochee hypothesis, with Latin stress rule, does not adequately explain the Wıìlıìdeh data, and the data are more consistent with iambic feet, the broader question one could ask regarding studies of this type is: why posit metrical feet at all? That is, since all of the different foot types examined in this paper are ultimately derived from position within the word (and location of the stem), syllable count, and tone, why not just state the phonetic results directly in terms of these more primitive categories? Indeed, metrical feet are almost always constructed from more primitive categories based on some set of automatic rules or constraints (Hayes 1995)—I am not aware of any language in which foot structure *per se* is contrastive. Accordingly, there are approaches to metrical phonology which do not make use of feet at all, but try to derive stress placement directly from these more primitive categories (Gordon 2002). For me, it is basically for reasons of descriptive convenience: an iambic analysis predicts that certain sets of observations will pattern together, which would not be predicted to pattern together otherwise. For example, in those few words I collected (not part of the original experiment design) which had long penultimate vowels, geminate consonants were also about 20% longer where the penultimate vowel was short, e.g. *gejį* [(ge.ˈdːʒį)] 'they are singing' compared to when the penultimate vowel was long, e.g. *geejį* [(ˈgeː)(ˈdːʒį)] 'they are afraid' (219 vs. 180ms, respectively). In this sense, 2-syllable words with a long penultimate stressed vowel pattern together with 3-syllable words, with all short vowels, and a (High-High-High) tone pattern, e.g. *k'egege* [(k'e.ge)(ˈgːe)] 'they are carrying a baby around'—in this case, the generalization is that geminate consonants are longer foot-medially than at foot boundaries. While it is of course possible to describe these types of observations without feet, metrical phonology provides a way to group these seemingly unrelated observations together in a way that makes interesting predictions. However, additional phonetic studies will be necessary in order to determine whether all of these predictions are supported by the data.

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