

Disentangling word stress and phrasal prosody: evidence from Georgian

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Abstract

This paper investigates the interaction of word stress and phrasal prosody in Georgian (Kartvelian). Based on experimental evidence, it shows that the two prosodic phenomena, word stress and phrasal prosodic targets, differ both in their location and acoustic means that their expression relies on. The results provide evidence in favor of fixed initial stress, cued by greater duration of the stressed syllable, as compared to subsequent ones. They also attest to the presence of a phrasal intonational F0 target on the penultimate syllable. The paper, therefore, illustrates the workings of the two separate prosodic modules, which have been commonly lumped together, leading to contradictory descriptions of Georgian prosody. Additionally, it shows that disyllabic prefixes are extrametrical for the purposes of stress assignment. In terms of their theoretical significance, these results help account for the facts related to word stress, phrasal intonation, and their interplay in Georgian, the object of numerous debates in the literature. They also demonstrate that the effects of word-level and phrase-level prosody can be teased apart, even in a language in which their interaction is rather complex.

Key words: Georgian, word stress, phrase accent, F0 targets, phrasal prosody

Introduction

When it comes to the issue of stress in a given language, the first questions to ask are the following: does a language have word stress? If so, how is its placement determined? Answering these may not be straightforward, especially in understudied languages. Consider the case of word stress in Hunzib, a small Tsezic language of Dagestan. Stress in Hunzib has been described as free and cued by F0 (Bokarev 1967: 474), fixed on the initial syllable and not relying on F0 (Gamzatov 1975: 18), initial but with numerous exceptions, driven by morphological factors (Isakov & Khalilov 2012: 78), penultimate and often accompanied by high F0, but not for all speakers (van den Berg 1995: 28), and mobile in certain paradigms (Lomtadze 1984: 145). Finally, Kibrik & Kodzasov (1990: 332) propose that Hunzib lacks word stress, but initial syllables carry phrasal accents.

Even when the questions above can be answered with confidence, there are further issues to consider. What acoustic parameter (syllable/vowel duration, F0, intensity) does the realization of word stress realization chiefly rely upon? How does its realization interact with the expression of phrasal intonation? Such issues have not been settled even in some better-studied languages, such as Korean or Turkish. In Korean, there is no agreement as to whether word stress exists, and, if it does, where its location is; initial or second (Lee 1973), second (Huh 1985), and final syllables (Polivanov 1936, as cited in Lee 1990) have been argued to regularly carry stress. More importantly, though, it is unclear if the phenomenon that has been analyzed as word stress in Korean is actually word-level stress or phrase-level prominence. Contrary to the previous accounts, Jun (1993) shows that stress placement in a word depends on its position in an accentual phrase, which suggests that the phenomenon at hand is phrasal in nature. Jun (1995) further shows, based on instrumental evidence, that whether the initial or second syllable is perceived as prominent

is determined by a combination of factors, such as syllable count, syllable weight, and the position of the phrase in a larger utterance; she also shows that the main acoustic cue that stress/prominence relies on is F0. These factors, taken together, suggest that what is described as ‘stress’ in Korean fits the profile of a phrasal intonational F0 target.¹

The language that this paper is dedicated to, Georgian (Kartvelian), shares most of the properties discussed above. Like Korean, Georgian has been variably argued to have either word-level stress, phrase-level stress, or both. There is no unanimity about the acoustic cues that stress in Georgian primarily relies on; initial, antepenultimate and penultimate syllables have been described as carrying stress, with more than one stress locus possible in longer words. Native speakers of Georgian have no consistent intuitions about stress placement, other than that stress never targets the ultima. There are no minimal pairs based on stress and no regular variation in stress placement in declensional or conjugational paradigms. Authors who advocate for the existence of word stress in Georgian acknowledge its acoustic weakness and often remark on the uncertainty of their observations (Robins & Waterson 1952; Zhghenti 1959; Tevdoradze 1978).

Based on experimental evidence, this paper provides evidence in favor of fixed initial stress in Georgian, cued by syllable duration, as well as the presence of a phrasal intonational F0 target on the penultimate syllable. The latter result aligns with a previously established fact of Georgian intonational phonology: penultimate syllables of predicates in narrow focus contexts and questions carry a low F0 target, which has been identified as a low phrase accent (Bush 1999; Vicenik & Jun 2014; Borise 2017). The two low F0 targets – the one discovered in the current study and the low phrase accent described in the literature – likely constitute two subtypes of the same phenomenon. In order to illustrate this, I also summarize the known distributional and analytical properties of the low phrase accent, which support its status of a phrase-level (as opposed to word-level) F0 target. I suggest that the generalizations concerning the low phrase accent should be extended to the low F0 target described here, thereby setting it apart from word stress. Beyond making a contribution to our understanding of the prosodic structure of Georgian, this paper, therefore, demonstrates that word-level and phrase-level prosodic phenomena can be told apart, even in a language in which their interaction is rather complex.

This paper is structured as follows. Section 1 lays the groundwork for the instrumental study discussed in the remainder of the paper. Sections 1.1 and 1.2 discuss existing research on word stress in Georgian (introspection-based and experimental, respectively), and Section 1.3 summarizes the key properties of Georgian intonational phonology. Building on these preliminary facts, the hypotheses to be tested experimentally are developed in Section 1.4. Section 2 reports on a novel instrumental study. After the design and stimuli are introduced in Section 2.1, Section 2.2 reports the results, for syllable duration (2.2.1), special behavior of complex prefixes (2.2.2), and F0 patterns (2.2.3). The theoretical significance of the current results is discussed in Section 3: Section 3.1 argues that the durational effect found on the initial syllable corresponds to word stress, and Section 3.2 shows that the F0 target on the penult matches the properties of a phrase accent. The theoretical implications of these results are addressed in Section 3.3.

¹ For Turkish facts, see Inkelas (1999), Inkelas and Orgun (2003), and Ipek (2015) for a view that Turkish stress is non-F0 based, and Kamali (2011) and Levi (2005) for a view that it chiefly relies on F0 as an acoustic cue. The two approaches also have different implications for the interplay of word stress with phrasal intonation: in Ipek’s (2015) study, both regularly accented and lexically accented words are analyzed as carrying pitch accents. Kamali (2011), in contrast, found that only lexically accented words but not regularly accented ones carry a H*L pitch accent. An even more diverse range of views on the existence, nature and interaction of stress with phrasal prosody is obtained in Malay/Malaysian/Indonesian; see e.g. Maskikit-Essed and Gussenhoven (2016).

Finally, the Appendix provides an overview of stress facts in the smaller Kartvelian languages (Svan, Megrelian, and Laz); though similar to those of Georgian in a number of respects, the stress facts of these languages present a number of additional puzzles, and still await detailed instrumental investigations.

1. Georgian prosody: the facts

Prosodic properties of Georgian have received a considerable amount of attention in the literature, with the existing descriptions based both on introspection by native speakers and instrumental observations. Nevertheless, there is no agreement in the literature as to the existence of word stress in Georgian or the rules governing its distribution. Initial, antepenultimate and/or penultimate syllables are most often quoted as possible stress loci, with potentially more than one of these carrying stress in longer words. The question about the size of a prosodic domain that ‘stress’ in question is assigned in – i.e., whether it is a lexical/prosodic word or a larger constituent, such as a prosodic phrase – has not been settled either.

1.1 Introspection-based accounts

Analyses advocating for the existence of word stress in Georgian vary according to whether they take (main) stress to target the initial, antepenultimate, or penultimate syllable; depending on syllable count, secondary stress may occur on one of the other loci.

According to Tschenkeli (1958: LX), Georgian stress targets the initial syllable in di- and trisyllables, and is harder to locate in longer words, though there, too, it is often initial. Tevdoradze (1978: 40) also describes Georgian as having fixed initial stress, but notes that secondary stress may occur in longer words: on the penult in tetrasyllables, antepenult in pentasyllables, and antepenult or preantepenult in hexasyllables. Antepenultimate stress placement, in turn, is advocated by Ioseliani (1840: 145), Gorgadze (1912: 3), Akhvlediani (1949: 135), and Gudava (1969: 106). Gorgadze notes that in longer words/phrases, the initial syllable receives secondary stress; exceptionally, if the antepenult consists of a vowel only, stress targets the preantepenult: *sáidumlo* ‘mystery’, *míirbina* ‘(he) came running’. Finally, Zhghenti (1958: 262) describes the Khevsuri and Mokheuri dialects of Georgian as regularly assigning stress to penults. At the same time, because he discusses, among other phenomena, penultimate stress placement before a question particle *-a* (*q’ačaghád-a?* ‘bandit-Q?’, *vín-a?* ‘who-Q?’), it is unclear if the phenomenon at hand should represent word stress or is part of phrasal prosody that characterizes questions.

In numerous accounts, Georgian stress placement is described as dependent on syllable count: initial in disyllables and antepenultimate or penultimate in longer words (Marr 1925: 13; Rudenko 1940: 24; Vogt 1971: 15), or initial in di- and trisyllables and antepenultimate in longer words (Dirr 1904: 3; Janashvili 1906: 5; Akhvlediani 1949: 132); Dirr (1904: 3) also notes that these rules apply regardless of the morphological makeup of a word. In words over four syllables long, a secondary stress on the initial syllable is possible; both are obligatory in words over six syllables long. A similar approach is adopted by Skopeteas & Féry (2016), who take disyllables to carry stress on the first syllable, and words of four syllables or longer to carry primary stress on the antepenult and secondary stress on the initial syllable. According to Aronson’s grammar (1990: 18), in words up to four syllables long, stress falls on the antepenult or the initial syllable, while in longer words both are stressed. Finally, according to Hewitt (1995: 28), in trisyllables, the initial syllable carries stress; in longer words, stress is either antepenultimate or initial.²

² Note that some of the sources that advocate for the existence of word stress in Georgian, based on impressionistic observations, are written by non-native speaker authors. Some caution is required when using these, since the authors might interpret acoustic

In contrast with the approaches above, some maintain that Georgian only relies on phrasal prosody, similarly to what has been suggested for French (Vaissière 1983; Jun & Fougeron 1995; 2000) or Iron Ossetic (Abaev 1939; Bagaev 1965; Isaev 1959). This view – that the domain of stress assignment in Georgian is larger than a prosodic word, making it phrasal stress rather than word stress – goes back to Gorgadze’s (1912: 13) notion of ‘syntactic groups’, Marr’s (1925: 14) ‘accentual complexes’, and Zhghenti’s (1953: 162; 1963: 144) ‘rhythmic groups’ as domains of stress assignment in Georgian. Some evidence supporting this view comes from traditional Georgian poetry, which is based on syllable count and not alternation of stressed and unstressed syllables (Gachechiladze 1968).

Finally, so-called mixed approaches advocate for there being both word stress and phrasal F0 targets in Georgian. This view is maintained by Chikobava (1942: 302) and Tschenkeli (1958: LXI), who point out that word stress in contemporary Georgian is considerably weaker than phrasal prosodic targets. It also has received some instrumental support, as discussed in the next section.

1.2 Previous experimental investigations

There have been several experimental studies of Georgian prosody, both word- and phrase-level, but since the two can be hard to separate, many studies address both. The conclusions that have been reached vary, much in the same way introspection-based reports do.

In one of the earliest studies, Selmer (1935) reports on an instrumental investigation of word stress in Georgian, based on recordings of one speaker pronouncing 27 Georgian words (20 disyllables, six trisyllables, and one tetrasyllable), some iterated twice, with the total stimuli count of 36. Measurements of F0 curves and vowel duration are reported. Selmer (1935) notes that the initial syllable invariably carries an F0 peak, but the average rise, being 2.64 St (semitones), is hardly significant. According to the duration measurements, in disyllables, the two vowels are almost equal in duration, while in trisyllables the second vowel is the shortest, with the two others being comparable in duration. With respect to vowel quality, Selmer notes that *i* and *o* have greater duration in the second syllable than *e* and *a*, unlike in the initial syllable, where vowel quality does not have a significant effect on vowel duration. Overall, Selmer cautiously interprets his results as consistent with Vogt’s initial assessment, later published as Vogt (1936; 1971), according to which di- and trisyllables are stressed on the initial syllable.

Robins & Waterson (1952: 58) arrive at different conclusions about stress placement, based on data collected from one speaker (number of stimuli not reported). According to them, word stress in Georgian is characterized by a rhythmic pattern, with alternating non-adjacent syllables carrying stress, as shown in Table 1.

Next, according to the results of Zhghenti’s (1953; 1959) production experiment, all syllables in Georgian words other than the final two are high in prominence (i.e., F0 values and intensity), while the final two syllables (or the final one in disyllables) are less so. Zhghenti’s results are based on the analysis of pitch-tracks of individual words two to six syllables long. The total number of stimuli or speakers is not reported, but a number of pitch tracks are discussed: disyllabic (n=6), trisyllabic (n=6), tetrasyllabic (n=7), pentasyllabic (n=4), and hexasyllabic (n=2). Zhghenti interprets his results as indicative of initial stress in di- and trisyllables; he takes both the initial and the second syllable to be stressed in tetrasyllables, and

cues that mark stress in their native languages as indicative of word stress in Georgian, especially if their background is in languages that have strong word stress, such as German, Russian or English.

refrains from interpreting the results for penta- and hexasyllables. Zhghenti's (1953; 1959) results are summarized in Table 1.

Table 1. Stress placement in Georgian according to syllable (σ) count (Robins & Waterson 1952; Zhghenti 1953; 1959)

σ count	Robins & Waterson, 1952	Zhghenti 1953, 1959	
	Stressed σ	Stressed σ	Prosodic make-up
2 σ	1 st	1 st	High F0 on the 1 st σ
3 σ	1 st or 2 nd	1 st	High F0 on the 1 st σ , high intensity on the 1 st and 2 nd σ
4 σ	2 nd or (1 st & 3 rd)	1 st & 2 nd	High F0 on the 1 st & 2 nd σ , high intensity on the 1 st , 2 nd and 3 rd σ
5 σ	(1 st & 3 rd) or (2 nd & 4 th)	?	High F0 and intensity on the 1 st , 2 nd and 3 rd σ
6 σ	1 st & antepenult	?	High F0 and intensity on the 1 st , 2 nd , 3 rd and 4 th σ

Other experimental studies, such as Alkhazishvili (1959), indicate that stress placement in Georgian interacts with information structure. This suggests that the prosodic phenomenon in question is phrasal in nature, since word stress placement typically does not depend on information-structural factors. To illustrate, variation of the sort *record* vs. *record* in English does not result from the same word being found in different syntactic or pragmatic contexts; cf. also Jun's (1993; 1995) results for Korean discussed in the introduction.³ In his investigation of Georgian prosody, Alkhazishvili (1959) argues for three types of information-structural contexts that condition stress placement in Georgian:

- Type I: broad focus utterances, typically with subject-object-verb (SOV) word order, as in (1);
- Type II: utterances with narrow focus on the preverbal constituent, as in (2);
- Type III: verb-initialthetic utterances, as in (3).

These utterance types, in Alkhazishvili's analysis, vary with respect to the distribution of "subject" and "predicate" prosodic phrases within them, which correspond to the notions of topic and focus/comment, or a logical subject and a logical predicate, respectively. The "predicate" includes the verb and the immediately preverbal focused constituent (if present), while the "subject" includes all the other material in a clause. According to Alkhazishvili, stress placement within a phrase is determined by its type.

³ There are certain instances where context, especially surrounding prosodic structure, can influence pitch accent distribution between syllables that carry a degree of stress. For instance, in English, in words carrying secondary stress on a syllable closer to the left edge of the word than primary stress, the syllable with secondary stress can carry a pitch accent if (i) the word is found at the left edge of an intonational phrase or (ii) the word is the only accented word in an utterance (Pierrehumbert & Talkin 1992; Shattuck-Hufnagel, Ostendorf & Ross 1994) – i.e., *thirteen* instead of *thirteen*. Note, however, that even in these cases the distribution of pitch accents is restricted to syllables carrying a degree of stress – i.e., the surrounding context determines pitch accent placement only between syllables already specified for a degree of stress.

- (1) [“Subject” *Giorgi-m*] [“Predicate” *pex-i ar ga-a-ndzr-i-a.*]
 G-ERG foot-NOM NEG PRV-VER-move-SM-AOR.3SG
 ‘Giorgi didn’t move’ (Alkhazishvili 1959: 373)
- (2) [“Predicate” *Omarašvil-ma da-i-xsn-a*] [“Subject” *gač’irvebi-dan samartal-i.*]
 O-ERG PRV-VER-save-AOR.3SG hardship-from court-NOM
 ‘It was Omarashvili that led the court out of the difficult situation.’
 (Alkhazishvili 1959: 380)
- (3) [“Subject” *Ga-vid-nen k’idev dgheni da tveni.*]
 PRV-go-IPFV.3PL more day.PL and month.PL
 ‘More days and months went by.’ (Alkhazishvili 1959: 385)

The results are based on the analysis of 21 recorded utterances: 12 of Type I, six of Type II, and three of Type III, pronounced by a male and a female native speaker. Two phoneticians, one of whom was a native speaker of Georgian, acted as analysts. Alkhasishvili (1959) reports that in “subject” phrases, which have an overall rising intonational pattern, initial stress is identified by the analysts, and this judgment is supported by instrumental data in approximately 80% of cases (it is not specified what acoustic cue this conclusion was based on). Alkhasishvili (1959: 402) also notes that there is no acoustic evidence for antepenultimate stress in “subject” phrases.

In “predicate” phrases, the picture is more complex. Here, in most cases, the analysts also identified stress as initial, but about 20% of “predicate” phrases were identified as having antepenultimate stress. This does not seem to depend on syllable count in the final word (typically the verb) in the “predicate”: “predicates” that include verbs consisting of as few as two or as many as five syllables were identified as carrying antepenultimate stress. Acoustic evidence for this judgement is scarce, and small sample size did not allow Alkhasishvili to reach a conclusion about its nature. The differences in stress perception between native and non-native speaker analysts are not reported either.

Finally, Jun et al. (2007) and Vicenik and Jun (2014: 156) report on a preliminary production study that found that the initial syllable in Georgian is characterized by higher intensity and longer duration. They also report a high-low tonal contour that spans the antepenult and penult, which they take to be a manifestation of phrase accent. Based on these results, they suggest that word stress in Georgian is fixed on the initial syllable, while the antepenult and penult are loci of phrasal intonational F0 targets. Borise & Zientarski (2018) arrive at the same conclusion – initial word stress and phrasal F0 targets anchored to the right edge of prosodic domains – based on a larger dataset.

1.3 Intonational phonology of Georgian

Issues of Georgian phrasal prosody/intonational phonology have attracted considerable scholarly interest, especially in recent years. Studies such as Tevdoradze (1978; 2005), Bush (1999), Müller (2005), Skopeteas, Féry, and Asatiani (2009; 2018), Skopeteas and Fanselow (2010), Asatiani and Skopeteas (2012), Jun, Vicens and Lofstedt (2007), Skopeteas and Féry (2010; 2011; 2016), and Vicens and Jun (2014) cover a wide range of issues, from prosody of neutral statements to that of questions and statements containing narrow focus. Jun et al. (2007) and, especially, Vicens & Jun (2014) provide a detailed Autosegmental-Metrical (AM) analysis of Georgian prosody, establishing the available levels of prosodic phrasing and inventory of F0 targets. The key insights of Vicens & Jun (2014) are provided below.

Each prosodic word in Georgian – defined as a lexical word, which may be accompanied by clitics, such as postpositions or discourse particles – forms an Accentual Phrase (AP). This is based on the fact that prosodic words in Georgian carry final boundary tones, which means that they also form minimal prosodic phrases, such as APs. As part of the unmarked intonational pattern of all-new, broad-focus declarative utterances, each AP, except for the right-most one, carries a rising F0 contour. Vicenik & Jun (2014) analyze it as a low pitch accent L* on the initial syllable of the AP followed by a high final boundary tone on the final syllable, Ha (where ‘a’ indicates that the boundary is part of the AP). Typically, downstep applies to each successive Ha. This pattern is illustrated in Figure 1 and Figure 2, with glosses provided in (4) and (5), respectively.⁴ Importantly for our purposes, the final high boundary tone is phrasal, and not associated with word stress; the rise in F0 and the F0 peak typically are contained within the final syllable. The full inventory of pitch accents and boundary tones available in Georgian can be found in Vicenik and Jun (2014).

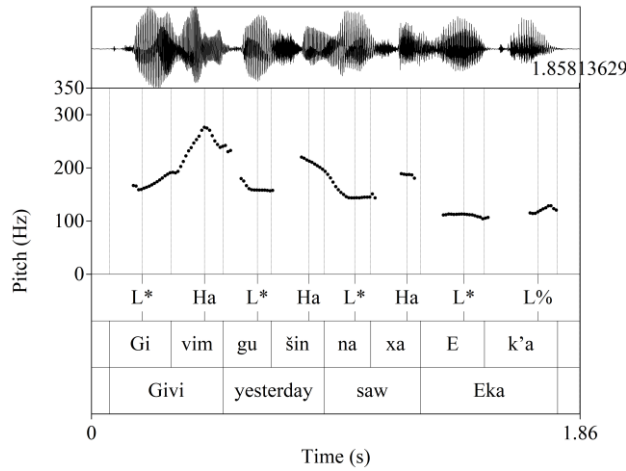


Figure 1. Declarative intonation in Georgian (1)

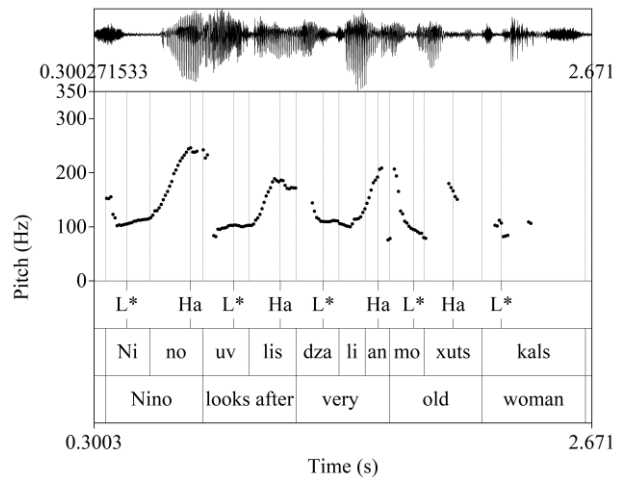


Figure 2. Declarative intonation in Georgian (2)

- (4) *Givi-m gušin nax-a Ek'a.*
 G.-ERG yesterday see-AOR.3SG E.-NOM
 ‘Givi saw Eka yesterday.’
- (5) *Nino u-vl-i-s dzalian moxuts kal-s.*
 N.-NOM VER-look_after-SM-PRS.3SG very old woman-DAT
 ‘Nino looks after a very old woman.’

In addition to the pitch accent and boundary tones, Vicenik and Jun (2014) advocate for there being another F0 target in Georgian – a phrase accent. In the AM literature, phrase accents have been variably analyzed as boundary tones for medium-level prosodic phrases, such as phonological phrases, or as F0 targets that are found between the rightmost pitch accent and a final boundary tone. (Bruce 1977; Pierrehumbert 1980; Ladd 1983; Grice, Ladd & Arvaniti 2000).⁵ With respect to Georgian, the distribution and properties of the phrase accent have been addressed in a number of studies. Specifically, it has been

⁴ The acoustic data used for illustrating the prosodic patterns of Georgian comes from author’s fieldwork in Georgia in 2016.

⁵ Phrase accents are known to have more complex distribution than other F0 targets, sometimes taking the form of pitch stretches or ‘elbows’, rather than being associated with a particular syllable. Their exact alignment is often hard to pin down (Del Giudice et al. 2007; Reichel & Salveste 2015; Flemming 2018).

noted that the penultimate syllable in Georgian, in certain contexts, is a locus for phrase accent realization. Due to its placement on the penultimate syllable, the phrase accent is reminiscent of the analyses postulating antepenultimate or penultimate word stress.

Let us briefly review the properties of the phrase accent in Georgian. In a study of the prosody of yes/no-questions in Georgian, Bush (1999) notes that penultimate syllables of verbs in yes/no-questions are always marked by a low tone, before a sharp rise on the final syllable. He takes the low F0 target on the penult to be (part of) a phrase accent, though notes that the precise anchoring of the low tone to the penultimate syllable is atypical of a phrase accent. Next, Müller (2005) in her study of the prosodic right periphery in yes/no-questions in Georgian also notes the low F0 target on the penult of the yes/no-question on the whole and takes it to be a phrase accent. Note that, since the questions in Bush's study were verb-final, Müller's findings also replicate those of Bush. Similarly, in Vicenik and Jun's (2014) analysis, an H+L phrase accent is found in yes-no questions, wh-questions, and narrow focus contexts, with the low and high portions of the phrase accent located on the antepenultimate and penultimate syllables of the verb, respectively. Finally, phrase accent is also taken up in Borise (2017), where two conclusions are reached. First, because Georgian allows non-final verb placement in questions, it was shown that the low F0 target is indeed associated with the verb. Secondly, the high F0 target that may precede the low tone on the penult does not occur in all contexts, which confirms the intuition that the low tone constitutes the main tonal element of the phrase accent.

To recap, there is robust evidence suggesting that, in Georgian, there exists an F0 target that is anchored to penultimate syllables in certain contexts – specifically, verbs in narrow focus contexts and questions. The very fact that the distribution of this F0 target makes reference to a particular information-structural context indicates that it is phrasal (as opposed to word-level) in nature. This is because phrasal prosody is known to vary based on an information-structural context – such as broad focus, narrow focus, etc. – while the locus or presence of word stress is not typically affected by these factors. Most importantly for our purposes, the existence of a phrase accent in Georgian is another factor to consider when interpreting the instrumental results.

1.4 Summary and research questions

To recap, there is no unanimity on the nature and distribution of stress in Georgia, and, additionally, stress interacts with phrasal prosody in an intriguing way. It seems uncontroversial that shorter words (di- and trisyllables) carry stress on the initial syllable, but the picture is less clear in longer words, where many authors note the presence of another stress locus on the antepenult or penult, with no agreement as to which of the loci carries main stress. Additionally, factors like information structure may affect the F0 contours of prosodic in a systematic way, which also influences the perceived location of word stress. In particular, prosodic phrases with topical interpretation (in Alkhazishvili's terms, "subject" phrases) are perceived as carrying initial stress, while prosodic phrases that are interpreted as focus/comment (for Alkhazishvili, "predicate" phrases) may instead be perceived as having (ante)penultimate stress.

In order to determine whether Georgian has word stress and tease it apart from the expression of phrasal prosody, there are several acoustic cues to be considered. Cross-linguistically, the expression of stress typically relies on cues such as duration, F0, intensity-based measures, and formant properties (Beckman, 1986; Gordon & Roettger, 2017; Hyman, 2006, 2014). Specifically, stressed vowels/syllables commonly have greater duration than unstressed ones (cf. e.g. De Jong & Zawaydeh 1999 on Jordanian Arabic; Eriksson & Heldner 2015 on English; Garellek & White 2015 on Tongan, among many others). Stressed

syllables may also carry a particular F0 target or contour, though, importantly, it is not always clear whether this F0 specification is lexical or post-lexical (i.e., phrasal) in nature. Finally, stressed syllables may be identified by intensity-based measurements, such as overall intensity (cf. Remijsen & Van Heuven 2005 on Papiamentu; Vogel, Athanasopoulou & Pincus 2016 on Hungarian), or frequency-sensitive intensity. In the existing studies of stress, duration is most often mentioned as an acoustic cue for stress, followed by F0, intensity, and formant and spectral qualities (Gordon & Roettger 2017). In turn, the expression of phrasal prosody most often relies on F0 targets, aligned with stressed syllables or edges of prosodic domains, though it may also be cued by effects such as final lengthening (Edwards, Beckman & Fletcher 1991), initial strengthening (Hock 1988), or glottalization (Dilley, Shattuck-Hufnagel & Ostendorf 1996), to name a few.

The questions that the current paper aims to answer, therefore, are the following: is there consistent evidence that certain acoustic cues (F0 targets, durational effects) are realized on particular syllables in Georgian? Given their nature and distribution, how are these cues best interpreted phonologically? Finally, how does this evidence relate to the existing descriptions and earlier experimental results available for Georgian?

2. Instrumental investigation

The current study builds on some of the previous instrumental work, especially Jun et al. (2007), Vicenik and Jun (2014), and Borise & Zientarski (2018). The small pilot study mentioned in Vicenik and Jun (2014:fn.1) reports greater duration of the first syllable as compared to subsequent ones in words of two to five syllables long. Vicenik and Jun take this durational evidence to be a manifestation of word stress, fixed on the initial syllable. The current study corroborates this conclusion, based on a greater number of speakers and range of stimuli than before. Furthermore, it provides solid evidence for the presence of an F0 target on the penultimate syllable, the prosodic signature of which aligns well with that on the phrase accent, as described in the literature.

2.1 Stimuli and design

The data for the current study was obtained from seven native speakers of Georgian: two males (M1, M2) and five females (F1-F5).⁶ All participants are natives of Tbilisi, with the age range 22-35 y.o., mean age 26.8 y.o. Speaker M2 was recorded in Tbilisi, Georgia, speaker F2 in College Park, Maryland, and the other five speakers in Cambridge, Massachusetts. Of the speakers recorded in the US, two have lived there for over seven years (F1 and F2), while another four arrived in the US less than a year before the time of the recording.⁷ The data from speakers F2 and M2 was collected using a lavalier microphone and an audio recorder in a quiet classroom; the other five speakers were recorded in a sound-proof booth. All data was recorded at the sampling rate of 44.100 Hz and 16 bits per sample.

The same set of stimuli was used for all speakers. The stimuli consisted of Georgian words (n=182), one to six syllables long, of CV structure (C = nasal, liquid, or voiced stop or fricative; V = any vowel),

⁶ One of the speakers whose data is used here, F2, was recorded by Xavier Zientarski, with the results of the preliminary investigation based on the speaker's data described in Borise & Zientarski (2018).

⁷ The duration of stay in the US did not give rise to significant inter-speaker differences. A mixed-effects model with duration of the initial syllable as dependent on speaker location (US long-term vs. other), with SPEAKER and TOKEN as random effects, did not detect any significant differences ($p=0.544$, $\beta=0.079$, $t=0.606$). Similarly, a model with F0 of the penultimate syllable as a dependent variable (other parameters held constant) did not detect significant differences between the two populations either ($p=0.434$, $\beta=0.22$, $t=0.281$).

and included nouns, adjectives, and participles.⁸ A representative sample of the stimuli is provided in Table 2; a full list of stimuli is available in the supplementary materials.⁹

Table 2. Sample stimuli

σ count	Sample stimuli	n
1 σ	<i>ra</i> ‘what’ <i>bu</i> ‘owl’	9
2 σ	<i>mama</i> ‘father’ <i>bude</i> ‘nest’	30
3 σ	<i>žižini</i> ‘bird twitter’ <i>malamo</i> ‘balm’	51
4 σ	<i>bagabugi</i> ‘thumping’ <i>monazoni</i> ‘monk’	55
5 σ	<i>gagorebuli</i> ‘rolled’ <i>ramodenime</i> ‘multiple’	33
6 σ	<i>gadanelebuli</i> ‘(water) taken off the heat’ <i>gadavadebuli</i> ‘rescheduled’	4
Total		182

Based on the observation, made in the existing grammars, that morphological structure is not a relevant factor in stress placement in Georgian, both mono- and polymorphemic stimuli were used. A post-hoc examination of the data revealed certain qualitative differences between words of different morphological make-ups, though these distinctions did not give rise to statistically significant differences. Nevertheless, detecting these trends allowed to account for the behavior of hexasyllables, which differs from that of shorter words, as shown in Section 2.2.1. Section 2.2.2 provides an account of morphological structure as a factor in the stress behavior of hexasyllables.

The stimuli were embedded in one of three carrier phrases:

- (6) a. *Me sit'q'va* [stimulus] *v-i-mgher-e*.
 1SG word.NOM 1SG-VER-sing-AOR.1SG
 ‘I sang the word [stimulus]’
- b. *Me sit'q'va* [stimulus] *v-i-xmar-e*.
 1SG word.NOM 1SG-VER-use-AOR.1SG
 ‘I used the word [stimulus]’

⁸ As part of the 182 stimuli, 15 non-words of three to five syllables were used; in the dataset, they were randomly interspersed with real words, in order to determine whether the real word vs. non-word status of a stimulus may affect its prosodic realization. During the analysis, disfluent non-word tokens, like disfluent real word ones (due to pauses, errors, list intonation, etc.) were discarded. No statistically significant differences in the behavior of remaining non-word tokens, as compared to that of real words, were detected. Exclusion of non-words from the dataset or their inclusion does not affect the results.

⁹ The variation in the total number of words with different syllable counts, as shown in Table 2, stems from several factors, such as the CV syllable structure requirement on the stimuli, the requirement for all consonants to be voiced, and avoiding consonant clusters. In particular, monosyllabic lexical words of CV structure are not numerous in Georgian, which led to their being only nine monosyllabic tokens in the dataset. Similarly, hexasyllabic words that adhere to the CV syllable structure template, contain only voiced consonants and no consonant clusters are considerably fewer than shorter words with the same characteristics. Accordingly, the total counts of words of two to five syllables are higher than those for shorter and longer words.

- c. *Me sit'q'va* [stimulus] *da-v-c'er-e*.
 1SG word.NOM PRV-1SG-write-AOR.1SG
 'I wrote the word [stimulus]'

The speakers were provided with a randomized list of all stimuli and, as a separate list, the three carrier phrases. They were instructed to pick each word from the list, one by one, match it with one of the carrier phrases, also picked consecutively, and pronounce the resulting combination. The two lists were kept separate in order to avoid the effect of reading the stimuli.

Each stimulus was iterated three times in a row – i.e., each type contributed three tokens.¹⁰ These two factors, combined – different verbs accompanying different experimental stimuli, and the fact that each stimulus was iterated three times in a row – were intended to decrease the likelihood of obtaining a contrastive reading on the consecutive stimuli. The stimuli that were pronounced with list intonation – occasionally, the first and/or the second iteration of the carrier phrase with the same stimulus – were discarded; rising F0 at the end of the carrier phrase was taken to be the main indicator of list intonation. Since no additional context was provided for the stimuli, embedded in the carrier phrases, their information-structural status is that of neutral/broad focus declaratives.

After eliminating disfluent tokens (due to pauses, speech errors, disruptions such as throat clearing, etc.), the final dataset consisted of 1,233 word types, which equals to 3,424 word tokens and 12,006 syllables. A breakdown of the dataset by speaker is provided in Table 3.¹¹

Table 3: The final dataset broken down by speaker

speaker	words		syllables
	types	tokens	
F1	178	526	1,856
F2	180	528	1,869
F3	180	534	1,864
F4	182	555	1,950
F5	182	537	1,893
M1	149	189	625
M2	182	555	1,949
Total	1,233	3,424	12,006

2.2 Results

The data obtained was manually annotated in Praat (Boersma & Weenink 2019) by trained research assistants, who segmented the data into words and syllables. Average values for duration and F0 of each syllable, as well as F0 at four fixed points throughout a syllable (left edge, 25%, 50%, 75%) were measured using a modified Praat script by Elvira-García (Elvira-García 2014); all F0 measurements were performed

¹⁰ Occasionally, a speaker would repeat the stimulus more than three times; for such speakers, the total number of tokens may exceed the total number of types multiplied by three.

¹¹ Speaker M1 contributed considerably fewer tokens to the dataset than the other speakers because, in his data, list intonation was found much more frequently than in other participants. His data is included into the final dataset in order to make it more gender-balanced. Exclusion of M1's data from the dataset or its inclusion into it does not affect the results.

in Hz. Statistical analysis of the data was carried out using the `glmer` function in the `lme4` package and the `lsmeans` function in the `lsmeans` package for R (R Core Team 2017).

2.2.1 Duration

The duration results are summarized in Figure 3. As one can see, the initial syllable has greater duration than all subsequent syllables in words two to five syllables long.¹² This tendency breaks down only in hexasyllables, which exhibit a rhythmic pattern in terms of syllable duration, with odd syllables having greater duration than even ones. The rhythmic durational pattern found in hexasyllables is further taken up in Section 2.2.2 where it is shown to be rooted in morphological factors.

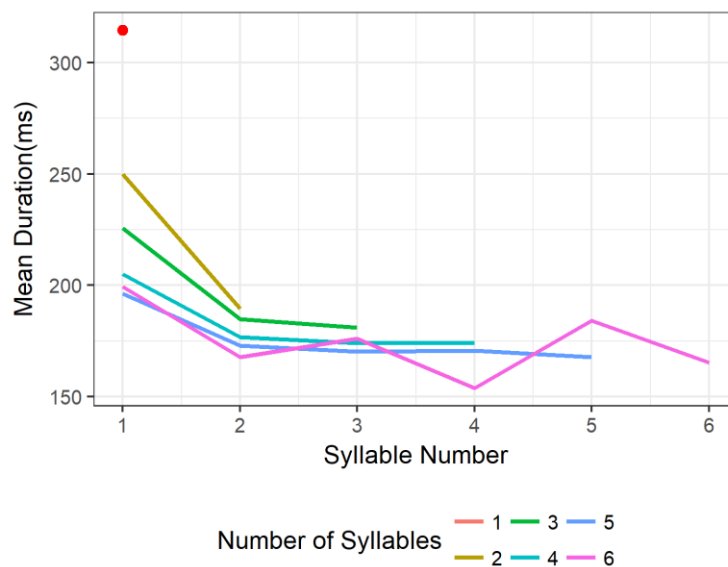


Figure 3. Syllable duration in words 1-6 syllables long.¹³

For a mixed effects model analysis, SYLLABLE DURATION was taken as the dependent variable, SYLLABLE NUMBER (1st, 2nd, etc; categorical factor) as a fixed effect and SPEAKER and ITEM as random intercepts. The model was run separately for words of each syllable count in order to have a group-specific intercept for each group, to account for the effect of polysyllabic shortening in longer words (Lehiste 1972). There was a significant effect of syllable number in words of all syllable counts. The average syllable durations in words of all syllable counts are provided in Table 4.

¹² Syllable duration rather than vowel duration alone is measured here. This is because the durational effect of stress may affect the consonant(s) in the stressed syllable, either in addition to or instead of the vowel: e.g. in Estonian stressed syllables are marked by lengthened onsets (Gordon 1995; Lehiste 1966), while in Welsh the same applies to codas (Williams 1999); for more examples and discussion, see Gordon and Roettger (2017). The inherent durational differences between onset consonants of different types (stops, liquids, and nasals) are captured by the statistical model with the random intercept ITEM.

¹³ Even though syllable duration is not a continuous measure, a line graph is used here in order to allow for an easy comparison between the durational properties of different syllables and words of different syllable counts.

Table 4. Average syllable duration in words 1-6 syllables long (ms) and significance values for all syllables in words 2-6 syllables long, as compared to the intercept (the initial syllable).

σ no. \rightarrow σ count \downarrow	1 st σ	2 nd σ	3 rd σ	4 th σ	5 th σ	6 th σ
1 σ	315					
2 σ	250	189 $p < 0.0001$ $\beta = -0.28$ $t = -28.56$				
3 σ	226	185 $p < 0.0001$ $\beta = -0.20$ $t = -26.9$	181 $p < 0.0001$ $\beta = -0.23$ $t = -30.28$			
4 σ	205	177 $p < 0.0001$ $\beta = -0.15$ $t = -20.01$	174 $p < 0.0001$ $\beta = -0.17$ $t = -22.45$	174 $p < 0.0001$ $\beta = -0.17$ $t = -22.91$		
5 σ	196	173 $p < 0.0001$ $\beta = -0.13$ $t = -13.09$	170 $p < 0.0001$ $\beta = -0.14$ $t = -15.04$	171 $p < 0.0001$ $\beta = -0.14$ $t = -14.71$	168 $p < 0.0001$ $\beta = -0.16$ $t = -17.07$	
6 σ	199	168 $p < 0.0001$ $\beta = -0.17$ $t = -8.35$	176 $p < 0.0001$ $\beta = -0.12$ $t = -5.76$	154 $p < 0.0001$ $\beta = -0.26$ $t = -12.53$	184 $p < 0.0001$ $\beta = -0.08$ $t = -3.98$	165 $p < 0.0001$ $\beta = -0.19$ $t = -9.01$
Mean (ms)	223	181	176	172	170	165
SD (ms)	54	38	41	41	44	35
Total n	3509	3334	2736	1673	680	74

Next, in order to determine how non-initial syllables compare to each other in duration, a pairwise post-hoc Tukey test was run for words of each syllable count. In words of two to five syllables, the Tukey test confirmed that the initial syllable is significantly greater in duration than all individual subsequent syllables. Some additional pairwise comparisons turned out to be significant: in trisyllables, 2nd and 3rd syllables ($p = 0.002$); in tetrasyllables, 2nd and 4th syllables ($p = 0.01$); in pentasyllables, 2nd and 5th syllables ($p = 0.0007$).¹⁴ In hexasyllabic words, the initial syllable was similarly greater in duration than all subsequent ones, and, in addition, all pairwise comparisons other than those between 2nd and 3rd and 3rd and 5th syllables lead to significance, which reflects the rhythmic pattern illustrated in Figure 3. The special behavior of hexasyllables is addressed in detail in Section 2.2.2.

Anticipating the discussion of the duration results in Section 3.1, there are two follow-up tests that need to be carried out in order to exclude some of the alternative explanations. First, it is worth checking whether the durational effect on the initial syllable might be driven by vowel quality; second, it should be verified

¹⁴ Put differently, in words of all syllable counts, a significant difference was found between the second syllable and the ultima; it is unclear at present what it might stem from. Note, however, that all p -values in the post-hoc test are larger than those derived from the comparison of initial syllables and all successive ones, as shown in Figure 3 and Table 4.

whether the prominent durational effect on the initial syllable results from an increase in the duration of the consonant, vowel, or both segments.

Turning to the first alternative explanation, it should be checked whether the initial syllables are greater in duration, across the board, because low vowels occur there more frequently than they do in subsequent syllables (since low vowels have inherently greater durations). In order to test for this, the full dataset was divided into two subsets, based on the height of the vowel in the initial syllable: non-high ([a, o, e]) in the first subset, high ([i, u]) in the second one. The mean duration of the initial syllable equals 224 ms in the first subset, and 220 ms in the second subset; a t-test revealed no significant difference between these two measurements ($p=0.08$). This shows that the durational effect that is associated with the initial syllable cannot be explained away as stemming from vowel quality.^{15, 16}

Next, consider the relative contribution of the two segments in the initial syllables – the consonant and vowel – to the duration of the syllable. In order to do this, relative duration of the segments within the initial syllable in Georgian was compared to that of the segments in a non-initial (second) syllable. A small subset of stimuli from the current study (n of tokens = 250), representative of the full dataset, was selected, and the initial and second syllables were additionally annotated for segment duration. Since all syllables in the study are of CV shape, the ratio of the two segments in different syllables can easily be compared.¹⁷ The resulting dataset consisted of 830 initial syllables annotated by segment, and 683 second syllables (the discrepancy between the two totals is due to the presence of monosyllabic stimuli). The segment duration results are provided in Table 5:

Table 5. Duration of individual segments in the initial and second syllables

Syllable	1st		2nd	
Segment	C₁	V₁	C₂	V₂
Mean duration (ms)	111	119	80	94
SD (ms)	36	40	19	24

As Table 5 shows, the increase in duration that the initial syllables receive, as compared to the second ones, does not result from the increase in the duration of either one of the segments – instead, both receive

¹⁵ The lack of a significant durational difference between vowels of different heights may seem surprising. There is some evidence, though, that only a marginal durational difference between vowels of different heights may be expected in Georgian: Shosted & Chikovani (2006: 262) found that Georgian /u/ and /ɔ/ largely overlap, and, likewise, /i/ and /e/ may have similar F1 properties. Given that vowel height is a predictor of inherent vowel duration, the fact that (some of) the high and non-high vowels have comparable F1 values is likely to contribute to the picture obtained here.

¹⁶ The duration results reported here contrast with Selmer's (1935) results (discussed in Section 1.2), according to which the syllables in disyllabic words were of equal duration, and the same was true of the initial and final syllables in trisyllables. The discrepancy between the two studies is likely due to the fact that Selmer's stimuli were not embedded in carrier phrases, and, as such, were subject to phrase-final lengthening.

¹⁷ A representative subset of the full dataset was created in the following way. 50 target types (from the total 182) were selected for additional annotation, which yielded 250 tokens. The distribution of syllable counts within the subset was the following: $n(1\sigma) = 9$, $n(2\sigma) = 10$, $n(3\sigma) = 11$, $n(4\sigma) = 7$, $n(5\sigma) = 9$, $n(6\sigma) = 4$. Since the first two syllables were the target of the additional analysis, their parameters were taken to be the crucial selection criteria. With respect to the C1V1C2V2 template, words with both identical and non-identical C1 and C2 and V1 and V2 were selected (in roughly equal ratios, i.e., per sample of stimuli of a given syllable count, ca. $\frac{1}{4} = CxVaCxVa$, $\frac{1}{4} = CxVaCyVa$, $\frac{1}{4} = CxVaCxVb$, $\frac{1}{4} = CxVaCyVb$).

an increase in duration. This can be illustrated by ratios between $C_1:C_2$ and $V_1:V_2$, which are 1.39:1 and 1.26:1, respectively. The fact that, in both ratios, the initial segments are greater than the second ones, shows that both segments within the initial syllable receive a degree of lengthening, as compared to their counterparts in the second syllable. Similarly, a t-test shows that the duration of vowels in the initial syllable is significantly greater than that of vowels in the second syllable ($p<0.01$), also indicating that the greater duration of the initial syllable does not stem from greater duration of the initial consonant alone. The significance of this fact is further taken up in Section 3.1.

2.2.2 Special behavior of disyllabic prefixes

Hexasyllables behave unlike shorter words with respect to syllable duration: here, instead of the initial syllable having greater duration than all others, a rhythmic pattern of alternating longer and shorter syllables is found. Since this pattern is also present in each speaker's individual data (not shown here), it cannot be idiosyncratic. The pattern in question was illustrated in Figure 3; Figure 4 shows the same effect with respect to the four individual hexasyllabic stimuli used in the study: *gadadughebuli* 'reboiled, overboiled', *gadagorebuli* 'rolled over, lolling', *gadanelebuli* 'taken off the heat (about water)', *gadavadebuli* 'rescheduled, suspended'. Note that the four tokens have uniform morphological structure: they are participles formed by the preverb *gada-* and suffixes *-eb-*, *-ul-*, and *-i*. Their morphological make-up is also where the key to their special behavior with respect to stress lies.

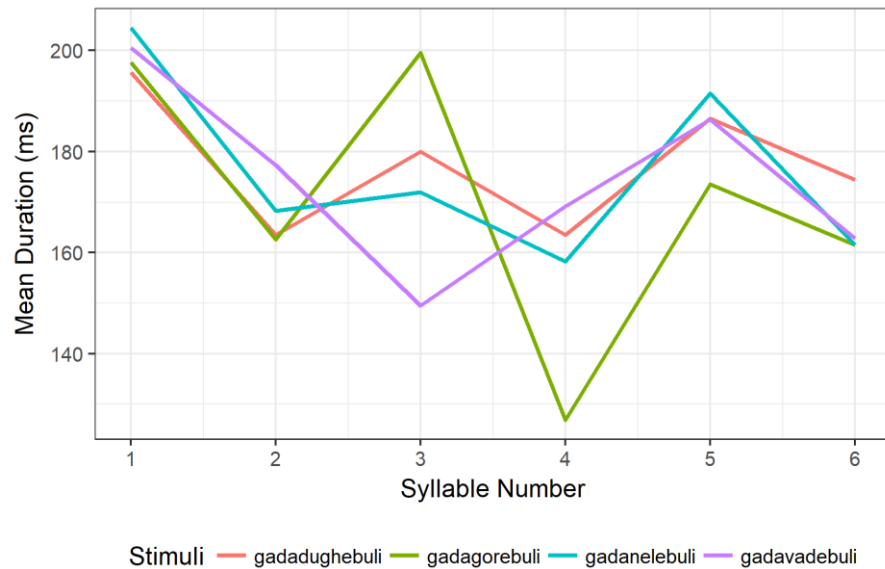


Figure 4. Average syllable durations (ms) in the hexasyllabic stimuli in the dataset

In order to find out whether morphological factors play a role in stress assignment, the behavior of words of the same syllable count but different morphological structures was compared. This included tetra- and pentasyllables, since shorter words in the dataset were overwhelmingly monomorphemic. Given that the aim of these additional tests was to explain the behavior of hexasyllables, which contain a complex (disyllabic) prefix *gada-*, the behavior of complex prefixes in shorter words was of special interest. Therefore, the tetra- and pentasyllables were divided into several groups, based on their morphological structure. Tetrasyllables formed three groups: words consisting of a root only, a root+suffix, or a simple (monosyllabic) prefix+root+suffix. Pentasyllables comprised four groups: root+suffix, simple prefix+root,

simple prefix+root+suffix, complex prefix+root+suffix. The total counts of words of each type are provided in Table 6.

Table 6. The total counts of tetra- and pentasyllables of different morphological structures

Morphological structure	Tetrasyllables	Pentasyllables
root	219	-
root+suffix	287	145
simple prefix+root	-	38
simple prefix+root+suffix	509	280
complex prefix+root+suffix	-	151
Total	1,015	614

The durational properties of words of different morphological structures, from both syllable counts, are presented in Figure 5 and Figure 6:

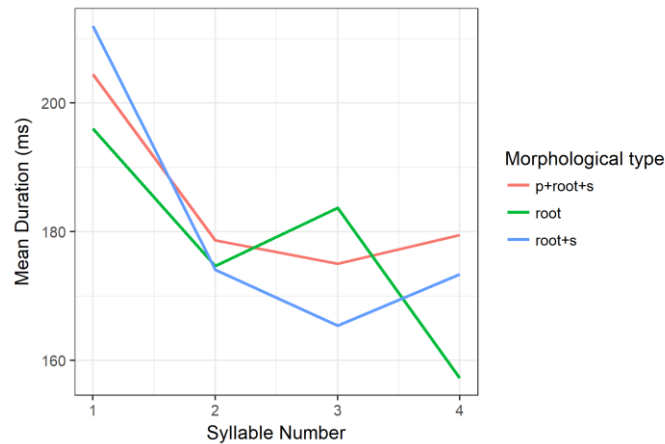


Figure 5. Average syllable durations (ms) in tetrasyllables of different morphological structures (p=simple prefix, s=suffix).

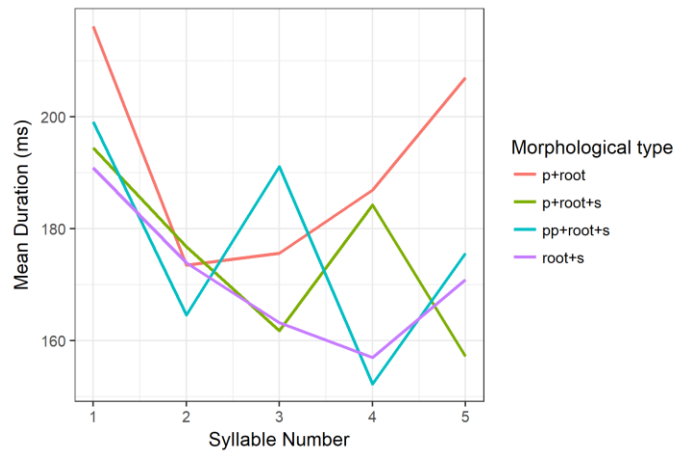


Figure 6. Average syllable durations in pentasyllables of different morphological structures (p=simple prefix, pp=complex prefix, s=suffix).

As Figure 5 shows, root+suffix and prefix+root+suffix words behave similarly; monomorphemic (root) words, in contrast, have a different pattern, with a ‘bump’ in duration on the penult, but the absolute durational differences between the penults are small (under 20ms) and did not turn out to be significant.¹⁸ Most importantly for our purposes, there is no difference in the behavior between non-prefixed words and those with a (simple) prefix. A very similar picture, with respect to non-prefixed words and those with (simple) prefixes, is obtained in pentasyllables, as shown in Figure 6: here, too, the initial syllables have the greatest duration.¹⁹ The morphological condition that stands out from all others is (complex) prefix+root+suffix – it is characterized by the same durational rhythmicity that we have seen in hexasyllables, which also include complex prefixes, in Figure 3 and Figure 4.

Taken together, these facts suggest the distinct behavior of words with morphological structure (complex) prefix+root+suffix, both penta- and hexasyllabic, is driven by the presence of the complex prefix *gada-*. The phonological significance of this observation is further taken up in Section 3.1.

2.2.3 F0 values

In order to compare F0 contours of stimuli of various syllable counts, an average F0 measurement per syllable was made, as shown in Figure 7. Additionally, F0 measurements were made at four fixed intervals per syllable (left edge, 25%, 50%, and 75% of total syllable duration). As Figure 8 shows, the data from these more frequent F0 measurements aligns with that in Figure 7 and, additionally, shows that monosyllabic stimuli carry the same F0 contour as the longer ones.

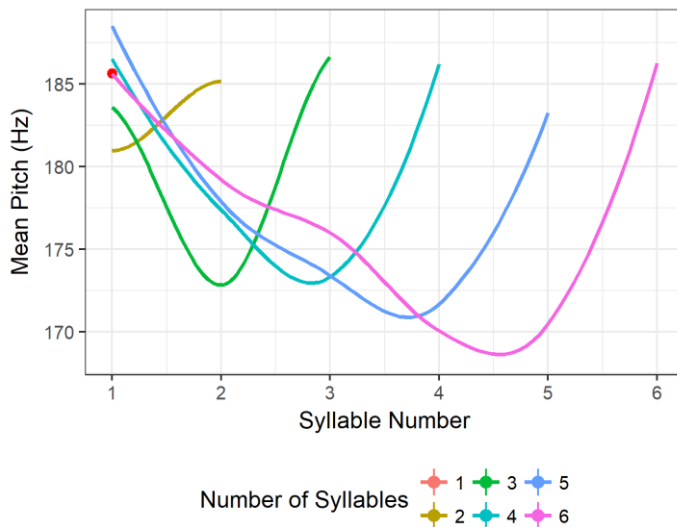


Figure 7. Average F0 values per syllable in stimuli of all syllable counts; smoothed at 0.8

¹⁸ With the prefix+root+suffix as the intercept, DURATION as the dependent variable, MORPHTYPE as a fixed factor, and SPEAKER and TOKEN as random effects, no significant difference was found between prefix+root+suffix and root ($p=0.39$, $\beta=0.06$, $t=0.86$), or prefix+root+suffix and root+suffix ($p=0.38$, $\beta=-0.05$, $t=-0.87$).

¹⁹ The only exceptions to this generalization are (simple) prefix+root+suffix pentasyllables, which have a durational ‘bump’ on the penult. It’s not immediately clear what this pattern stems from, though note that this is not a consistent trend: tetrasyllables of prefix+root+suffix shape do not have it.

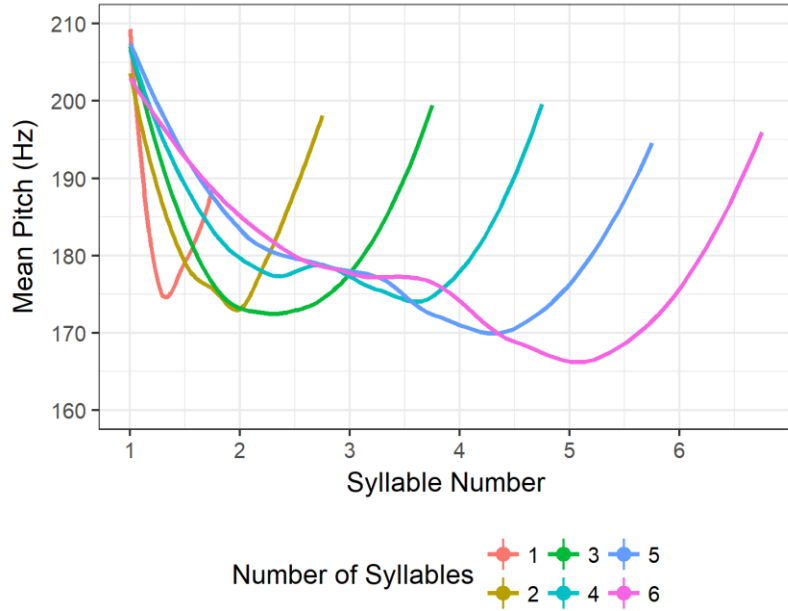


Figure 8. Average F0 values at four points per syllable in stimuli of all syllable counts; smoothed at 0.8; each numbered tick mark corresponds to the left edge of the respective syllable.

As Figure 7 and Figure 8 show, words of all syllable counts have an overall falling-rising F0 contour. The key alignment properties of the rise and fall in F0 are made particularly clear in Figure 8, especially in longer stimuli. As one can see in Figure 8, both the lowest F0 point per word and the final rise are aligned with the right edge of a prosodic word. In particular, the lowest F0 values are found on the penultimate syllable, whereas the rise in F0 is always confined to the ultima. That is, in words of all syllable counts, the penultimate syllable acts as a turning point between the falling and rising subparts of the F0 contour. As per Figure 8, the same F0 pattern is found in mono- and disyllables; in the former, both tonal movements are realized within a single syllable, while in the latter the lowest point is found on the boundary between the two syllables.

Average F0 values per syllable (right to left), for words of all syllable counts pooled together, confirm this observation: the F0 peak on the ultima (mean=185.88Hz) is preceded by a trough on the penult (mean=172.94Hz), which is in turn preceded by higher average value on the antepenult (mean=176.1Hz). To test the significance of this generalization – that there is a consistent F0 pattern on the right edge of words of all syllable counts, with a gradual fall from the left edge to the penult and a sharp rise on the ultima – a mixed-effects model analysis was used. For words of each syllable count, the penultimate syllable acted as the intercept; F0 (at the mid-point of a syllable) was taken to be a dependent variable, the position of a syllable within a word as a fixed effect and SPEAKER and ITEM as random intercepts. There was a significant effect of the syllable position on the F0 value in words of all syllable counts tested. The results of the statistical analysis and average F0 values per syllable are provided in Table 7.

Table 7. Average F0 values per syllable in stimuli of all syllable counts (Hz) and significance values for all syllables in words 2-6 syllables long, as compared to the intercept (the penultimate syllable).

σ no. → σ count ↓	1 st σ	2 nd σ	3 rd σ	4 th σ	5 th σ	6 th σ
1 σ	185.62					
2 σ	180.95	185.13 $p < 0.0001$ $\beta = 0.07$ $t = 10.21$				
3 σ	183.59 $p = 0.002$ $\beta = 0.02$ $t = 3.02$	172.83	186.67 $p < 0.0001$ $\beta = 0.09$ $t = 12.26$			
4 σ	186.5 $p < 0.0001$ $\beta = 0.05$ $t = 6.86$	177.37 $p < 0.0001$ $\beta = 0.05$ $t = 6.57$	173.32	186.19 $p < 0.0001$ $\beta = 0.1$ $t = 14.75$		
5 σ	188.49 $p < 0.0001$ $\beta = 0.08$ $t = 9.87$	177.87 $p < 0.0001$ $\beta = 0.08$ $t = 9.32$	173.40 $p < 0.0001$ $\beta = 0.04$ $t = 4.46$	169.22	183.91 $p < 0.0001$ $\beta = 0.1$ $t = 12.81$	
6 σ	185.96 $p < 0.0001$ $\beta = 0.12$ $t = 5.48$	176.99 $p < 0.0001$ $\beta = 0.12$ $t = 5.97$	176.85 $p < 0.0001$ $\beta = 0.08$ $t = 4.19$	170.05 $p = 0.045$ $\beta = 0.04$ $t = 2$	168.4	187.75 $p < 0.0001$ $\beta = 0.12$ $t = 6.14$
Total n	3509	3334	2736	1673	680	74

To sum up the F0 results, words of all syllable counts adhere to the same generalization: a gradual fall from a high F0 target at the very left edge of the initial syllable leads to the lowest F0 point on the penultimate syllable, followed by a sharp F0 rise on the ultima.

3. Discussion

To recap the findings from Section 2.2, the initial syllable in Georgian has greater duration than all subsequent syllables in words two to five syllables long. The absolute duration of the initial syllable decreases as the number of syllables in a word increases, due to polysyllabic shortening. In contrast, hexasyllabic words exhibit a distinct rhythmic pattern, with longer and shorter syllables alternating.

In terms of F0 properties, in words of all syllable counts, the penultimate syllables have consistently lower F0 values than the surrounding syllables, with F0 values gradually falling from the left edge of the word to the penult, and sharply rising again on the ultima. Both right and left edges of the stimuli in the current study are marked by high F0 values. On the right edge, the rise in F0 spans the final syllable. Left-edge high F0 values, in contrast, are found at the very edge of the initial syllable, with the steepness of the fall determined by the syllable count (the fewer syllables, the steeper the fall in F0), with the lowest F0 found on the penult.

It is apparent that the acoustic properties that commonly mark word stress or phrasal prominence, such as greater duration or the presence of an F0 target, regularly anchor to the initial and penultimate syllables,

respectively. This is consistent with the existing literature that takes the initial and/or penultimate syllables in Georgian to be the stress loci. Notably, the results provide no evidence for antepenultimate stress. This is consistent with Alkähzishvili (1959: 402), who, similarly, found no acoustic evidence for antepenultimate stress. Thus, it is unclear what, if anything, contributes to the speakers' perception of antepenultimate syllables as carrying stress.

Before delving into the discussion of the phonological interpretation of the results, note that, as discussed in Section 1.3, the high F0 target on the ultima is known to be phrasal, and independent from word stress. Therefore, the ultima is not considered as a potential locus of stress going forward.

3.1 Duration-cued initial stress

As discussed in Section 2.2.1, initial syllables in Georgian are consistently marked by greater duration than all subsequent syllables. Phonologically, duration-cued word stress, fixed on the initial syllable, is a possible source for it, but there is also a prominent alternative explanation. Specifically, greater duration of the initial syllable can also stem from initial strengthening – a phonetic process that applies to left edges of prosodic domains and is independent of stress.

The two processes that can affect the duration of the initial syllable – word stress and initial strengthening – have different phonetic signatures (Barnes 2008). Initial strengthening affects the duration of the absolute initial segment but does not extend to the vowel in the initial syllable, while word stress can contribute to greater duration of the initial syllable on the whole (cf. also Fougeron & Keating 1997; Byrd, Krivokapić & Lee 2006). To tease the two apart, the relative contribution to syllable duration made by the consonant and the vowel in the initial syllable should be addressed.

The results of the test were presented in Table 5 in Section 2.2.1. According to them, the greater duration of the initial syllable results from greater duration of both the consonant and the vowel in the initial syllables, as compared to their counterparts in the second syllable. This would be unexpected from the point of initial strengthening alone, which only targets the absolutely domain-initial (here, word-initial) segment, not both segments within the initial syllable. With the main alternative explanation, initial strengthening, ruled out, the best interpretation for the durational effect discovered here is that it is the acoustic cue that the expression of stress, fixed on the initial syllable, relies on.

The presence of word stress on the initial syllable, therefore, straightforwardly accounts for the durational effect found on the initial syllable in words two to five syllables long. With respect to hexasyllables, recall from Sections 2.2.1 and 2.2.2 that they are characterized by a 'rhythmic' durational pattern, with longer and shorter syllables alternating. This effect, as argued in Section 2.2.2, is driven by the presence of the complex prefix *gada-* and is also found in *gada-*prefixed pentasyllables. Analytically, I suggest that it stems from the extrametrical status of *gada-* (and, possibly, other complex prefixes, not tested here). The prefix causes the root following it to behave as if it were non-prefixed, with the initial syllable of the root having greater duration than the next one. The prefix itself also adheres to the same durational schema: its initial syllable is greater in duration than the following one. This strong-weak+strong-weak pattern seems to set off a 'ripple effect', with the remaining syllables in a word adhering to the same rhythmic pattern.

How about the F0 properties of the initial syllable? Recall that the very left edge of the initial syllable, in words of all syllable counts, is marked by high F0 values. Nevertheless, several pieces of evidence go against the hypothesis that the initial syllable is associated with an F0 target. First, as discussed in Section 1.3, the default F0 contour found on non-final prosodic words in Georgian is a rising one, with each word

starting with relatively low F0 and ending with higher F0 values. With respect to the right-edge high F0 target, Vicens and Jun (2014) show that it is a final boundary tone that marks the smallest prosodic phrases, formed by individual prosodic words, Accentual Phrases. Crucially for the current argument, Vicens and Jun (2014) also found no evidence for a left-aligned high F0 target. The strongest support for the conclusion that there is no high F0 target associated with initial syllables comes from APs that are initial in a larger utterance; cf. Figure 1 and Figure 2. Not preceded by another AP that ends in a high final boundary tone, these APs have consistently low F0 values on the left edge. Therefore, the most plausible explanation for the high F0 values on the left edges of the stimuli is that they are carried over from the F0 peak associated with the ultima of the preceding word (part of the carrier phrase that precedes the stimulus). The fact that the highest F0 values are found at the very left edge of the initial syllables and are immediately followed by a fall in F0 throughout the rest of the initial syllable (with the steepness of the fall depending on syllable count) supports the idea that these syllables do not carry a high F0 target themselves.

To recap, the distribution of syllable duration provides strong support for the presence of word stress on the initial syllable. This durational effect may be obscured in words with complex prefixes, which are extrametrical, and may give rise to a ‘rhythmical’ durational effect throughout the rest of the word. There is no evidence for consistent alignment of F0 targets with the initial syllable.

3.2 Phrasal F0 target on the penult

One of the consistent F0 effects discovered here is that penultimate syllables, in words of all syllable counts, carry a low F0 target, followed by a sharp rise on the ultima. All syllables preceding the final two are characterized by a shallow fall in F0 towards the penult.²⁰ The emergent generalization, therefore, is that the F0 contour of a prosodic word in Georgian consists of two F0 targets, a low one on the penultimate syllable, and a high one on the ultima, as was shown in Figure 7, Figure 8, and Table 7.

One way of analyzing the two phonetic phenomena described so far, the durational effect on the initial syllable and the F0 effect on the penult, would be to suggest that Georgian has a polar/dual stress system (Gordon 2002; van der Hulst 2014), in which the primary and secondary stresses are fixed at the opposite edges of a prosodic word. However, it is unclear how such an analysis would account for the patterns found in di- and trisyllables. In particular, in trisyllabic words, these two loci are adjacent, and in disyllabic words they coincide, which is possible to see since the two effects are signaled by different acoustic cues, duration and F0. Such behavior is atypical of two degrees of stress, which usually resist being adjacent, let alone overlapping.

Therefore, it is more analytically sound to conclude that the penultimate syllable in Georgian is reserved for F0 targets that are part of the right-edge intonational make-up of a phrase (cf. Gordon 2014), and does not carry word stress. The next question is what type of an F0 target it is. The inventory of F0 targets available in Autosegmental-Metrical (AM) theory includes pitch accents, phrase accents, and boundary tones (Lieberman 1975; Bruce 1977; Pierrehumbert 1980; Ladd 1983; Gussenhoven 1984; Beckman & Pierrehumbert 1986; Pierrehumbert & Beckman 1988, a.o.). Pitch accents are anchored to syllables that carry a degree of stress, while boundary tones are aligned with edges of prosodic domains. It is unlikely

²⁰ This aligns well with Zhghenti’s (1953; 1958) experimental results, in which F0 values were found to drop on the penult and ultima of the stimuli. The fact that the ultima, in Zhghenti’s results, did not have high F0 values, unlike in the current study, is likely due to the fact that his stimuli were not embedded in carrier phrases, and, as such, were subject to right-edge effects characteristic of declaratives, which typically end in a low tone. Jumping ahead, in Autosegmental-Metrical terms, this means that the phrase accent L, aligned with the penult, may be followed by either a H% or a L% boundary tone.

that the F0 target discussed here is a pitch accent, since pitch accents align with stressed syllables, and, for the reasons listed above, it is implausible that the penult carries a degree of stress. It is equally unlikely that the low F0 target on the penult is part of a complex final boundary tone, ‘crowded out’ to the penultimate syllable. This is because it has been independently shown that Georgian can accommodate bitonal boundary tones on the final syllable, such as HL% (Vicenik & Jun 2014; Borise 2017), which makes it clear that the F0 target on the penult is independent from the boundary tone on the ultima.

The final prosodic category to consider is a phrase accent. As discussed in Section 1.3, penultimate syllables in Georgian, in certain informational-structural conditions, such as questions and narrow focus contexts, carry a low phrase accent L. The distribution of the low F0 target found on the penultimate syllable in the current instrumental study resembles that of the phrase accent described in the earlier literature. I suggest that this is not accidental resemblance. The distributional properties of the phrase accent and the low F0 target found on the penultimate syllables in the current study are a perfect match: both are strictly anchored to the penultimate syllable, in words of all syllable counts. Therefore, the most parsimonious approach to the two F0 targets is to treat them as two subtypes of the same phenomenon. This, in turn, means that the distribution of the phrase accent in Georgian is broader than has been described before and is not limited to questions and narrow focus contexts. The exact information-structural conditions that may influence its distribution await further investigation.

3.3. Conclusions and theoretical implications

Based on instrumental evidence, this paper identified and provided interpretation for some regular acoustic cues that are utilized in Georgian prosody. Specifically, it established that initial syllables in Georgian words is marked by greater duration than subsequent syllables. After excluding initial strengthening as an alternative explanation, this effect is best phonologically interpreted as stress, which is fixed on the initial syllable and cued by syllable duration. This result aligns well with the existing literature on Georgian prosody, which consistently lists the initial syllable as the locus of prosodic prominence and a possible stress locus. Nevertheless, morphological effects, such as the presence of a complex prefix, may obscure this effect, and contribute to a different, ‘rhythmic’ syllable duration pattern instead. With respect to F0 effects, the results confirmed the presence of a high final boundary tone at the right edges of APs, as described in the literature. They also showed that penultimate syllables, in words of all syllable counts, consistently carry a low intonational F0 target. Based on what is known about the phrasal prosody of Georgian, this F0 target is most parsimoniously analyzed as a phrase accent. The two loci of prosodic prominence, initial and penultimate, therefore, operate on different levels (word stress vs. intonational F0 target), and rely on different acoustic cues. These results contribute to separating the two levels of prosodic structure in Georgian and resolving the conflicting views that surround word stress placement in the language.

These conclusions also have implications for the theory of word stress. Recall that stress in Georgian is morphophonologically ‘inert’. On the phonological front, speakers do not have consistent intuitions about stress placement. With respect to morphology, stress placement is not subject to regular variation in declensional or conjugational paradigms. The fixed nature of Georgian stress, as advocated here, may be a contributing factor to both kinds of ‘inertia’. Specifically, languages with fixed stress are known to have a weaker acoustic expression of stress than languages with variable/contrastive stress placement (Cutler 2005; Dogil 1999; Fónagy 1966; Janota 1967; Jassem 1962; Rigault 1970). Speakers of languages with fixed stress have weaker intuitions about stress placement, including in other languages – so called ‘stress-deafness’ (Dupoux & Peperkamp 2002; Dupoux, Peperkamp & Sebastián-Gallés 2001; Dupoux et al. 1997;

Peperkamp & Dupoux 2002; Peperkamp, Vendelin & Dupoux 2010). The fact that Georgian falls into the category of languages with fixed stress, therefore, may explain the reported ‘weakness’ on Georgian stress, and lack of consistent intuitions on behalf of the speakers. On the morphological front, fixed stress, naturally, cannot be contrastive.

There are further implications for the workings of prosody in languages with so-called weakly implemented stress. First, the results discussed here suggest that other languages described as having ‘weak’ stress may, in fact, be languages with fixed, morphophonologically ‘inert’ but still identifiable stress (instead of not having the category of stress at all). The results discussed here show that such languages might present evidence for word stress, even though it does not play a role in other phonological processes in the language, and speakers do not have strong intuitions about it. In connection with the latter, note that Georgian stress has been shown to interact with narrow focus in a systematic way (Skopeteas & Féry 2016; Borise 2019).

Most importantly, the evidence from Georgian discussed here shows that certain cases of complex interplay between word- and phrase-level prosodic effects can be disentangled with the help of more detailed instrumental evidence; the hope is that the same can be done in other languages in which the issue of stress is rife with questions.

Appendix: Word stress facts in other Kartvelian languages

Georgian is the biggest and the best studied of the four Kartvelian languages, including in terms of its prosodic properties. In order to provide a broader perspective for the facts of Georgian prosody, and to encourage the study of the prosodic properties of the smaller Kartvelian languages (Megrelian, Laz, and Svan), this Appendix provides an overview of the stress-related prosodic properties of the smaller Kartvelian languages.

The prosody of Megrelian, Laz, and Svan has not received as much attention as that of Georgian, and many facts are still unclear. Yet, based on the available literature, there are some noticeable similarities among these languages. Specifically, in all Kartvelian languages, two possible loci for word stress are usually mentioned in the literature: the initial and the antepenultimate/penultimate syllable. Furthermore, authors frequently observe that the penultimate/antepenultimate locus, but not the initial locus, may be accompanied by a change in F₀, and possibly constitutes a phrasal intonational F₀ target.

In Megrelian and Laz the realization of word stress is reportedly weaker than in Georgian and Svan (Amirjebi-Mullen et al. 2006:88). There is agreement in the literature that in disyllabic words in Megrelian stress is initial. Kluge (1916:3) claims that in longer words stress is penultimate, and accompanied by high F₀; cf. a claim by Chikobava (1942: 302) that there is evidence for a tonal accent on the penultimate syllable in the Pazar and Ahavi dialects of closely related Laz. Kipshidze (1914: 13), on the other hand, argues that Megrelian words of four syllables or longer have two stresses, primary on the initial syllable and secondary on either the penult (in tetrasyllables) or the antepenult (in longer words). Final vowels in Megrelian are often lengthened, especially in the Zugdidi dialect (Gudava 1969: 109), which has also been analyzed as final stress (Tsagareli 1880: 7; Kiziria 1967: 65). Chikobava (1942: 302) hypothesizes that both Megrelian and Laz used to have tone-based stress at an earlier stage. A recent instrumental study by Poniava (2020) reveals considerable variability with respect to acoustic cue alignment in Megrelian words.

A detailed account of word stress in one dialect of Megrelian (Senaki) is provided in Gudava (1969) and summarized in Harris (1991). According to it, in consonant-final words, stress falls on the penult, while in vowel-final ones – on the antepenult; that is, Senaki Megrelian exhibits sensitivity to heavy vs. light final syllables which is reminiscent of the Latin stress rule or recessive accent in Greek. As an exception to this generalization, certain verbs ending in short vowels have penultimate stress, regardless of their phonological make-up. These include perfective future forms, certain aorist forms, and other lexical exceptions. Availability of these exceptional patterns leads to minimal pairs: *dóghuru* ‘s/he died’ (lexical exception), *doghúru* ‘s/he will die’ (regularly accented) (Gudava 1969: 109).

In Laz, stress is penultimate in non-verbs (Marr 1910: 4; Öztürk & Pöchtrager 2011: 18). In verbs, stress placement is tied to particular slots in the template for affixal morphology. Specifically, stress is rightmost in the part of the stem up to and including the perfective causative marker; all suffixes following the perfective causative marker repel stress, as shown in (7).

- (7) *d̤ʒe-m-i-t̤ʰ-am-áp̤^h-ur-t̤^h*
 PRV-1SG-PR-beat-AUG-CAUS.PRF-TS-PL
 ‘I have beaten you (pl.) before’ (Öztürk & Pöchtrager 2011:18)

If there is no perfective causative marker, stress is placed as far right as possible, save for the stress-repelling affixes, as in (8):

- (8) *p'-ts'óp̤^hx-i-k'o-t̤^h*
 1SG-build-1SG.PST-COND-TS
 ‘If we built it. /Let us build it’ (Öztürk & Pöchtrager 2011:43)

In some dialects of Laz, such as Atina (today’s Pazar) and Ahavi (Chikobava 1942: 302), as well as Batumi (Adjarian 1899: 99), there is some evidence for high tone regularly appearing on the penult as well, though it is unclear if the high tone is attributable to word stress or phrasal prosody.

In Svan, according to the literature, stress usually targets the penult or the ultima. There might be a tendency for stress to stabilize on the penult (Zhghenti 1949: 100), but stress placement interacts with other processes, such as umlaut, vowel length and vowel reduction, some of which are poorly understood, which makes stress facts harder to grasp. There is also considerable dialectal variation (Tuite 1998: 9). Long vowels in Svan often carry stress: *má:re* ‘man’ vs. *maré* ‘but’ (Zhghenti 1949: 97). At the same time, there is no one-to-one correspondence between stress and vowel length, as up to four long vowels per word are attested: *kæ:di:ya:læ:n* ‘got undressed’²¹ (Tuite 1998: 8). A number of suffixes, both nominal and verbal, are pronounced as long and viewed as stressed (Zhghenti 1949: 100), though it is unclear if this lengthening is due to word stress or phrasal intonation: *dedber-i:l* ‘old woman’, *ts'ir-ó:l* ‘hammer’, *iqve:zi-é:l* ‘slumber’. Some of these suffixes are also marked by noticeable tonal movement, especially in the Lashkhian and Upper Bal dialects (Zhghenti 1949: 101; Zhghenti 1960: 101). Certain particles, such as *-i* ‘too’ and preverbal negative particles are always stressed (Zhghenti 1960: 99, 103).

Overall, the prosodic properties of the smaller Kartvelian languages, based on the available descriptions, resemble those of Georgian. In all Kartvelian languages, there is a noticeable tendency for targets associated with F0 changes to be found on the penultimate syllable, with the initial syllable also

²¹ Stress placement is not marked in this form in the source.

carrying some degree of prominence, likely not F0-based. However, given the brevity of the available descriptions, it is impossible to say if these targets constitute word stress or are parts of the phrasal intonational pattern. Stress-related properties of all three smaller Kartvelian languages await instrumental investigation.

Abbreviations

1 – first person, 2 – second person, 3 – third person, ABS – absolutive, AOR – aorist, AUG – augment, CAUS – causative, COND – conditional, DAT – dative, ERG – ergative, IPFV – imperfective, NEG – negation, NOM – nominative, PL – plural, PR – pre-root vowel, PRF – perfective, PRS – present, PRV – preverb, PST – past, SG – singular, SM – stem marker, TS – thematic suffix, VER – version vowel.

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