becoming lyrics: how word prosody and musical meter negotiate the rhythmic terms of prominence

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I think that when linguists discuss and dispute sound length and stress among themselves they would definitely benefit from inviting ethno-musicologists to join them. They could discuss the issues together, and not only based on written records but also sung records.

That what is written is fiction. Only that what is sung is truth.

Tormis (2007)

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Chapter 1

Introduction

1.1 On words becoming lyrics

To join song and become lyrics, meaningful linguistic material must be modified to fit the strict temporal structure of music, while both poet and performer are tasked with preserving intelligibility sufficient for semantic interpretation of the whole. Thus the rhythm of language must fit into the song's rhythm, but enough of the language's own rhythm must remain in order for the lyrics to have meaning. The study of metrical prosody often focuses on the patterns in the texts independent of the songs. In this paper, I analyze the acoustic-phonetic correlates of linguistic rhythm *within* the context of the song. That is, I aim to see how the text-setting of metrical verses is acoustically realized by performers of an oral folksong tradition. I define metrical as the mapping of the pattern on a frame formed of equal time intervals: such patterns have been demonstrated to be more easily replicated by humans, something that is necessary for both the synchronization of musicians performing together and for the transmission of an oral tradition of songs (Essens & Povel, 1985). Previous studies have compared acoustic measurements with transcriptions of previously not annotated music. The problem with these transcriptions is that they "cannot be wrong," in some cases, the transcriber

was noncommittant to a measure's value; in others, the subjectivity of human perception is the obstacle. In the present study, I use the annotations as a starting point for each song, but introduce the use of beat-tracking algorithms to provide a rigorous definition of the location of beats, while simultaneously bringing both replicability and falsifiability along.

1.1.1 Phonetics of Estonian Prosody

Q1	sada	kabi
	'hundred'	*'hoof'*
Q2	saada	kapi
	'send'	*'of the cupboard'*
Q3	saada	kappi
	'recieve'	*'into the cupboard'*

Table 1.1: ternary syllable weight contrast

Estonian is famous for its ternary quantity distinction: both vowels and consonants have three distinct lengths or degrees. As can be seen in the examples in 1.1, the length of a given segment can indicate lexical contrasts as in sada vs saada ('hundred' vs 'send') (root minimal pairs) and also indicate case: the difference between 'receive' and 'send' is in the quantity of the first syllable' or directional case marking 'of' versus ''into' the cupboard.

1.1.2 Metrical Structure in Music

In music, the smallest prosodic constituent is an individual note event whose relationship to the other notes in the song are indicated by the time signature, i.e., $\frac{3}{4}$ and $\frac{4}{4}$. The denominator corresponds to the number of di-

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visible beats of a "whole" note (𝅝), while the numerator refers to the number of "beats" in a single measure. In $\frac{4}{4}$, a whole note is sustained for the same duration as four quarter notes (♩) in the same measure, and each measure must culminate in enough notes and rests to equal a whole note.

1.1.3   Metrical Principles of Estonian folksong

Estonian *regilaul* is part of the Finnic runosong tradition shared by several other members of the Finnic language family: Finnish, Karelian, Votic, Ingrian, and Livonian (Ross & Lehiste, 2001). The metrical basis of the tradition is a trochaic tetrameter often referred to as the Kalevala meter (Oras, 2019), which is realized in Estonian 20th century work as syllabic-accentual trochaic tetrameter (Lotman & Lotman, 2013).

Each verse line has four beats with eight syllable-note positions which can also be occupied by rests or, in the case of trisyllables, two sixteenth syllable-notes. The "beat" or "ictus" position falls on the note corresponding to the first beat of a measure, and on every other following syllable-note in the invariant form of eight eighth notes. Runic songs that follow quantity rules for trochaic meter oppose metrically strong and weak positions by means of syllable quantity and stress. Ictus position, or on the beat, prefers syllables that are both long and stressed but avoids short stressed syllables: these can occur off the beat, while this position is avoided by long syllables. These "singable songs" (Tormis, 1985) follow a metrical pattern such that a given *regilaul* text can be sung to any of the numerous *regilaul* melodies (Ross &

Lehiste, 2001).

Figure 1.1: "Millal saame sinna maale"

1.1 illustrates the invariant pattern of eight syllables notes each occupying one eighth of a $\frac{4}{4}$ measure.

Figure 1.2: notation of "Loomine" performed by Liisu Orik in 1965

1.2 illustrates a melody variation with seven syllables: in the first verse, the last (heavy) syllable is extended to fill a quarter note, in the second the last syllable is sung as an eighth note and followed by a quarter rest (𝄾).

How do the word-prosodic requirements negotiate with the imposed prosodic hierarchy of music? The rhythmic organization of song is said to integrate the prosodic structure of the language with musical rhythmic principles (Palmer & Kelly, 1992). However, earlier studies of *regilaul* explored

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temporal aspects of the songs and found that duration characteristics that would usually indicate important semantic differences lost their distinctions partially or entirely. Assuming that the intention of the singer is for the lyrics to be understood, I hypothesize that if some durational correlates of contrasting word-prosodic constituents are made less distinct in the process of compromising with the song that some other acoustic correlate of the relevant contrast at the word-prosodic level will be present, if not enhanced.
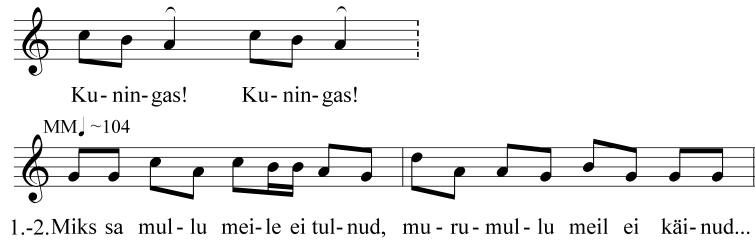
Figure 1.3: music notation of "The King Game" as performed by Liisa Kümmel

1.2 Previous Studies with *regilaul*

The intuitions of those who study the runosong tradition is that the burden of upholding the temporal structure of the song is the result of symbiosis between the musical rhythm and the natural prosodic features of the lyrical text (Ross, 1992; Tampere, 1934): the song's melody a musical abstraction of the natural prosody of spoken runic verse inspiring decades of research at the interface of metrical phonetics and computational musicology Rüütel (1999).

Swinging songs are characterized by a swinging rhythm with alternating

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Figure 1.4: The swinging song 'Kiik tahab kindaid' analyzed in Ross (1989, 1992)

long and short notes, differing from the main body of *regilaul*'s iconic isochrony. Jaan Ross, a musicologist and native speaker of Estonian analyzed a 1936 recording of the swing song 'Kiik tahab kindaid' 1.4, publishing results on syllable-note duration Ross (1989) and later the vowel quality of odd-numbered syllables (Ross, 1992). In the study on syllable-note durations,

In the second, Ross measured formant frequencies f1 and f2, finding a reduced vowel space in song compared to measurements in spoken Estonian. However, upon examination of the song, it is clear that all the vowel space measurements are from syllable-notes in non-initial positions of Estonian words: that is, the sample of vowels taken from the song were all unstressed, and compared to a mixed sample of spoken Estonian. Thus, the conclusion needs to be evaluated again with comparable samples.

In 1992, Ilse Lehiste asked "Whether there is a correlation between poetic metre and the prosodic structure of a language.(Lehiste, 1992) by means of measuring the acoustic-phonetic realizations of so-called trochaic metrical po-

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etic patterns across several languages including Estonian and Finnish. While these languages share in the more general Balto-Finnic tradition of *runosong* utlizing what is called the *Kalevala* meter, there were significant differences in the phonetic realizations of trochees in each language.

In 1994, their collaboration begins. Ross and Lehiste published several papers examining the temporal dimensions of Estonian word prosody and metrical prominence in *regilaul* folksongs. In (Ross & Lehiste, 1994), they conclude that duration differences ordinarily present at the word level (stressed-unstressed) are *"lost"* to the temporal restrictions of the song. In another paper, syllable-notes are again measured, this time examining the role of syllabic quantity in the song. They likewise conclude that the duration of syllable-notes in *regilaul* match more closely with the metrical structure of the songs, that is, the durations of syllable-notes are best predicted by their beat position in the song: on the beat, syllables are longer, off the beat shorter. They extend this finding to conclude that the song "dominates" the metrical status of the words, claiming that the intelligibility of lyrics is enhanced more strongly by "top-down" processes (i.e., semantic context).

(Ross & Lehiste, 1996).

(Ross & Lehiste, 1998) Analyzed and concluded that the *regilaul* lyrics are the result of an interaction between word and song prosodic hierarchies. This conclusion relied critically on measuring the durations of syllable-notes, where they found being on or off the beat was the better predictor for duration.

Finally, in (Ross & Lehiste, 2001) summarize their body of work until that point and extend their findings with fine-grained acoustic phonetic measurements of segment durations within syllable-notes. In their discussion, they mention that some of the durational differences not present at the syllable-note level are present at the segmental level, in complex codas.

1.3   The present study

To extend the findings of this body of work, the present study examines two acoustic correlates of prominence at the segmental level: namely, the syllable nucleus. Because the vowel is the most sonorant part of a syllable, it is the most acoustically and perceptually salient portion of the syllable. Measuring the vowel duration will also offer indirect information about the rhyme as a whole: the presence of codas and complex codas should have an effect on the vowel duration in isochronous syllable-note sequences. In the cases where quantity is distinguished by coda consonant length, the syllable nucleus (measured by vowel duration) will be necessarily shorter to accommodate the geminate or complex coda. In cases where quantity is indicated by the length of the vowel, the opposite should be true. This study therefore examines the ternary quantity distinction in the context of its syllable shape: no coda (CV), single coda (CVC, CVVC), and complex coda (CVCC, CVCCC) rather than collapsing all syllable shapes according to their quantity. This allows a closer look at the microprosodic features at the segmental level.

In addition to vowel duration, I also include vowel dispersion measured by the euclidean distance from the center of each singer's vowel space on the (f1, f2) plane. A larger vowel perimeter generally corresponds to hyper-articulation or clear speech, while a smaller perimeter with hypo-articulation or reduction Lindblom (1990); Smiljanić & Bradlow (2005). In natural Estonian speech, reduction is only allowed on unstressed syllables, with /i/ being the most resistant (Eek & Meister, 1998). This measurement is included for two reasons: one, the acoustic correlates of prominence in both language and music are almost always not a single cue but a convergence of several cues, and two, to see if the findings of (Ross, 1992) extend to the style of *regilaul* songs that make up the largest portion of the body of work (i.e., non-swinging songs).

More recently, syllabic-accentual trochaic tetrameter has received some statistical attention to its textual structure (Lotman & Lotman, 2013)

and to rhythmic variation in singing (Oras, 2019).

1.3.1 Hypotheses

Null hypothesis: on or off-beat position is best predictor for vowel duration of syllables in all categories: stressed, unstressed, short, long, and overlong. This would mean that the syllable nucleus is proportional to the total syllable duration, and that the duration contrast is indeed "lost."

H_1: duration contrasts for syllable quantity will be evident in the vowel duration, with vowel duration *decreasing* as syllable weight increases. Given the findings of (Ross & Lehiste, 2001), isochronous syllable-notes would result

in heavier syllables having shorter nuclei to accommodate for the coda and complex codas that distinguish the syllable weights from each other.

H_2: stress/unstress contrasts will be evident in the nucleus in terms of hypo and hyper articulation. For this I measure both nucleus duration and vowel space dispersion.

Chapter 2

Methods

2.1 Phonetics of Metrics in Estonian Word Prosody

Primary lexical stress in native Estonian words is fixed, falling on word-initial syllables. There are no stress minimal pairs at the lexical level: thus, primary stress is said to be *demarcative* or *identificational*(Lehiste, 1992), functioning to indicate the boundary of a new word. Syllables following primary stress are unstressed, and secondary stress is attested to fall on each odd syllable in polysyllabic words. Duration functions at several levels of Estonian prosody: it is the strongest correlate of both clear speech and stress (Lippus et al., 2014) when compared with measurements of f0 and spectral emphasis, and is independently contrastive at the segmental level as illustrated in minimal triads in **??**. Secondary stress was found to be significantly different in duration from both primary and peninitial unstressed syllables: interestingly, secondary stressed syllables were not shown to differ greatly from their even-positioned neighbors (excepting the peninitial). For the sake of simplicity, this study focuses only on the contrast between first (primary stressed) and second (unstressed) syllables.

In primary stress position, there are three contrastive syllable quan-

tities. The first (Q1) is described as short, the next (Q2) as long, and the heaviest (Q3) as overlong.

Q1	Q2	Q3
kodi	*koodi*	*koodi*
/ko.ti/	/koː.ti/	/koːː.ti/
	koti	*kotti*
	/kot.ti/	/kotː.ti/
	gooti	*kooti*
	/koːt.ti/	/koːtː.ti/

Table 2.1: segmental permutations of initial syllable quantity

In the first row of **??**, we see a minimal triad of the ternary quantity contrast in open first syllables. The Q2 and Q3 columns demonstrate all the other ways this contrast can be realized using the same segment identities in closed syllables.

(1) laul-da
[lɑu̯l.dɑ]
sing-TR

   'singing'

(2) ööbik

   [øː.pik]

   nightingale.NOM

   'nightingale'

Q1 and Q2 syllables can be both stressed and unstressed, while Q3 is only present in stressed positions, attracting stress to its (non-initial) syllable in

compound and loan words. Peninitial syllables can only be Q1 or Q2, illustrated in 2.

2.2 Constructing the Corpus

I first describe the source materials and the selection criteria for the sample corpus of *regilaul* folksongs. Following this, the annotation and measurement procedure is detailed. Then the procedure for assembling the corpus of songs and their text annotations is covered before proceeding to the inclusion criteria for vowel duration and dispersion measurements.

2.2.1 Materials

Songs for this paper were accessed via The Anthology of Estonian Traditional Music (Tampere, 2016). Originally published on four vinyl discs in 1970, the digital version showcases a robust sample of the massive collection of *regilaul* in Estonian Folklore Archives. In addition to audio, the compilation includes photographs, sheet music, and performer demographics of 98 *regilaul* songs and 17 instrumental tunes. These songs were compiled in part by Herbert Tampere, an early ethnomusicology field work organizer of the EFA, who along with Erna Tampere and Ottilie Kõiva collected these folk songs(Oras & Västrik, 2002; Tampere, 2016).

While the ultimate goal is to continue annotation of the entire available corpus of *regilaul*, for the initial analysis I chose a sample of songs all belonging to the same regional dialect and recording method. Once several regions were

identified as possible candidates, a native Estonian speaker was consulted on the final selection. The nine songs analyzed in this study were all recorded in Parnümaa county from 1961-1966 by Herbert and Erna Tampere.

2.3   Annotating the Song Audio

Each song's lyrics are copied from the site and saved as .txt files in Estonian orthography, each line of the file corresponding to one melody line. Audio files of the selected songs are downloaded from the archive in .ogg format, which is the highest resolution of the two lossy formats available from the digital anthology. Each song is then imported into a Logic Pro X (Cousins & Hepworth-Sawyer, 2014) session for beat detection, tempo mapping, and trimming. To make the tempo map, the session must be set to *flex tempo*. From here a beat onset detection algorithm is given the transcribed bpm and time signature from the archived song data and run on the imported audio file. The result is an annotation of intervals in time, and the bpm for each measure is annotated according to the performance of the song. The tempo map allows us to document when *exactly* in time the particular singer performed a given note, the duration of the sung note, and the acoustic threshold by which the note is defined as "strong" relative to surrounding notes. The process is informed by the transcribed bpm and time signature included in the anthology. This is beneficial to my purposes in two ways: by accounting for the natural tempo variation in live performance, and by using a consistent metric to determine beat strength acoustically rather than just perceptually. Using onset

detection algorithms such as these (Robertson & Plumbley, 2007) in phonetics research, especially in the interdisciplinary field of linguistics and musicology, will be particularly beneficial to answering questions about rhythm: finding a way to bring our intuitions and impressions about "the beat" together with the acoustic phenomenon. By automating the annotation and measurement process using open source tools, the author hopes to share these machines with those who have similar research interests, and also to invite contributors to the data of this corpus of text data time-aligned to queryable audio signal data. From here, a MIDI track is programmed to create a metronome that is the length of a single syllable-note in the song. In most of these, a 4/4 measure contains eight eighth notes, so the metronome track contains four eighth notes indicating the "ictus" beats. In flex tempo mode, the MIDI track adjusts note and measure length to match the fluctuations in tempo as documented in the map for the song. The metronome and the song audio file are trimmed to match exactly, and the metronome is converted into a textgrid in PRAAT(Boersna & Weenink, 2022), where the annotation process continues.

The orthographic text phrases of the song lyrics are then inserted into each phrase interval with a script, and then eSpeak forced aligner for Estonian (Duddington et al., 1995) is run on each phrase to the word and phonemic level. Because this forced aligner is trained on spoken, not sung Estonian, the aligner sometimes tries to align words into the signal before they are uttered. In these cases, the word level tier is manually realigned so that it contains all and only the transcribed word, and then the forced aligner is re-run on

this word to the segmental level. "Giving" the forced-aligner all and only the correct word improved the segmental alignment, but the relevant segments for this study were manually verified and adjusted (if necessary) to ensure they all met a consistent criteria.

2.3.1 Criteria for adjusting the forced-aligner

Manually verified the intervals set by the forced aligner for syllable nuclei according to the frequency and intensity contours in PRAAT. The beginning of the vowel was broadly aligned according to a combination of acoustic correlates: at the point where 1. intensity was within 2dB of the steady-state medial portion of the vowel with a slope between 0.5 and zero, 2. frequency stabilizing into that syllable-note's pitch category, and 3. the presence of a voicing bar and visible formants f1, f2, and f3. Manner specific criteria: did not include burst in plosives. Boundaries between fricative onsets and vowels was determined by the end of visible high-frequency noise in the spectrum. Coronal fricative /s/ also consistently showed a carat **??** in the frequency track immediately preceding the transition to vowel. For approximants, the additional criteria of steady formants was necessary. Following nasal onsets, vowel intensity *lowered*, but a near-zero slope still reliably coincided with the other acoustic correlates.

The offset boundaries of vowels was set similarly, but instead with slopes less than or equal to -1 in their transition to occlusions. The first three formants were more variable in transition to codas, so the other cues were

relied on more heavily.

Closed syllables with approximant codas /l/ were excluded, as neither the forced-aligner nor the phonetician could determine a reliable way to define the boundary between them. In onset position, the boundary between approximant and vowel was more consistently definable by the above criteria (with the additional requirement of steady formants, which generally coincided with the frequency and intensity cues). In cases of vowel adjacency across syllable boundaries, the presence of a visible glottal stop and a similar (though not as strict) pattern to the above criteria would qualify both for inclusion. In the absence of these cues, both nuclei were excluded from the measurements. Other exclusions were due to ambient noise (i.e., churchbells in song 41), ambiguity of word boundaries due to wordplay or nonse words (verified by native speaker informant), and cases where the transcription indicated epenthesis or severe reduction.

In all cases, if the aforementioned cues were unavailable, ambiguous, or misaligned, the token was elided for this analysis. From all nine songs in the corpus, a total of 757 vowel nuclei met the criteria for inclusion in duration measurements.

At this point, the audio recording of each song has tiers annotated for tempo and strong beat, verse line phrases, two interval tiers force-aligned to word and phoneme levels, and a separate tier with intervals of the individual vowel segments of interest copied from the phoneme tier.

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2.3.2 Fusing audio-aligned transcriptions with text corpus

The last step in preprocessing is to integrate the annotation of the song audio with the lexical content of the song. This study accomplishes the task using an open-source natural language toolkit in python called estinltk `https://github.com/estnltk` (Laur et al., 2020). Among other things, the toolkit has a robust dictionary of Estonian grammar, including phonetic transcription of syllables with corresponding quantity and stress data.

Thus the data structure of this corpus offers two independent metrics of rhythmic prominence in these songs. From the audio recording and the beat detection, we have an annotation of strong beats based on replicable acoustic measurements, and from the dictionary in the natural language toolkit, we have native speaker intuitions about the lexical weight and prominence in the words of the text. While the stress system is generally predictable, the syllable quantity is not always apparent from the orthography, and not always detectible by a non-native listener.

Once the annotations are complete, the corresponding text files are aggregated and, the corresponding measurements from PRAAT are concatenated via python using the parselmouth library python interface to PRAAT (Jadoul et al., 2018; Van Rossum & Drake Jr, 1995).

Only those vowels from syllables that were nominally transcribed as isochronous eighth notes and also coincided with the beat length provided by the flexible MIDI metronome were used for this study. Syllables in the final

position of the verse were excluded due to the tendency for variation in the final notes of the phrase.

2.3.3   long vowels and monophthongs

An estonian word game supports the notion of many-to-one phonemes for long vowels, but a one-to-one status for diphthongs.

(3)   long vowels (Q1,Q2, Q3 contrast)

- sada 'hundred' → sapida

- saada 'send' (2nd sg. imp.) → sapiida (*sapiada)(*saapida)

- saada 'get' , -*da* infinitive → sapii:da (*sapiada)(*saapida)

(4)   diphthongs

laulus 'in the song' (iness.sg) → lapiulus (*laupilus)

In both cases, 'pi' carries the prosodic characteristics of the displaced syllable. the stress is moved from first syllable to 'pi,' and also the length. crucially, the diphthong is split at the segmental level, while the long vowels are not. Long vowels, then, are treated as monophonematic, whereas diphthongs are treated as biphonematic.

This word game supports the notion that long (identical) vowels and diphthongs in Estonian should potentially be treated as different categories for duration. The analysis therefore will examine long monophthongs and diphthongs both together and separately for interpreting the measurement of vowel duration.

Lehiste (1985)

2.3.4 Statistical Analysis

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†LaTeX is a document preparation system developed by Leslie Lamport as a special version of Donald Knuth's TeX Program.