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Comparing Lithuanian Folk Scales with Historical Temperament Systems in Lithuania and the USA

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The novelty and relevance of the idea of this artistic research lies in the comparison of the intervals of the traditional Lithuanian unequal tunings and the European and Middle Eastern unequal temperament systems in order to identify the degree of similarities and differences of interval distances. The novelty also lies in the extent of the research object, which included Lithuanian folk music recordings from the first half of the twentieth century preserved in Lithuania and the USA. It could be argued that the twelve-tone equal temperament (12-TET) has influenced Lithuanian traditional tunings, but several studies carried out on traditional Lithuanian vocal and instrumental music show that the 12-TET is not widespread. However, the micro-intervals in Lithuanian music have retained their uniqueness and distinctiveness compared with neighbouring countries (Latvia, Estonia, Poland, and Finland), where no natural intervals and tuning of traditional scales has been detected. The project objective is the comparison of unequal tuning systems with Lithuanian folk music scales using computer technologies. The research methods used during the project were: (a) comparative method, a study of European and Asian unequal systems based on the temperaments of natural harmonic series and the traditional Lithuanian music scales; (b) the software R statistical analysis method, using a file system to process text information. It can be concluded that there are many cases of natural intervals found in Lithuanian folk songs, considering that the temperaments of previous centuries had some naturally tuned intervals.

KEYWORDS: Lithuanian folk scales, interval distances, unequal temperament systems, microtones, natural intervals, 12-TET

Introduction

Before the twenty-first century, the field of interval relations in Lithuanian folk music was not considered very important, as many Lithuanian and foreign scholars were not interested in the analysis of pitch distances in the scale which determines the different interval relations, widening the experience of listening and perception. Therefore, the hypothesis has now been raised that by comparing the intervals of 12-TET[1] and natural harmonic series, it is possible to explain the tunings of traditional Lithuanian music, which were based on tradition, but the gradually changing tuning system at the turn of the twentieth century was supposed to have undergone the transformation to 12-TET. Are natural intervals and micro-intervals common in Lithuanian folk music scales? It can be argued that the Lithuanian folk songs of the early twentieth

1 12-TET (12-tone equal temperament) is a system of equal temperament in which the octave is divided into 12 equal semitones. In Europe, this tuning system replaced earlier tuning systems that were based on acoustic principles of interval tuning derived from the harmonic series. In 12-TET, the distance of each semitone is equal to 100 cents. Other systems of equal temperament divide the octave into different numbers of equal parts, such as 19 (19-TET), 24 (24-TET, used in Arabic music), 31 (31-TET), 72 (72-TET).

century still retained the intonations of traditional tunings, presumably preserving the intonation features and intervals of unequal distances that could change or redefine the structure of the scale.[2]

As early as the interwar period, the composer Jeronimas Kačinskas[3] (1907–2005) wrote about the microtonality of these scales in his article 'Praha – kūrybinės muzikos iniciatyvos miestas' (Prague – the city of creative musical initiatives):

If we look at the music of our own past (small horns, panpipes, wooden trumpets, etc.), we will find a multitude of intervals smaller than semitones [emphasis by V. G.]. It must be assumed that in ancient times the Lithuanians did not know the Greek and German major and minor keys. This is probably the influence of later centuries.[4]

The ethnomusicologist Jadvyga Čiurlionytė (1898–1992), a researcher of Lithuanian folk songs, wrote about the necessity of micro-alteration marks when notating Lithuanian folk songs in her *Tautosakos rinkėjo vadovas* (Folklore Collector's Handbook) published in 1940.[5] Genovaitė Četkauskaitė (1925–2021), the pioneer of the phonetic transcription of Lithuanian folk melodies, began to use arrow signs in her transcriptions.[6] The musicologist Vytautas Venckus (1922–1997) referred to the principles of natural harmonic series and described the harmonic peculiarities of Lithuanian folklore, stating that 'the fourth and the fifth have a special importance in the harmonic structure, and therefore these intervals form the framework of the tones in the scale'.[7]

It is worth mentioning that in his theory book *Akordo sąndaros klausimu* (On the Structure of the Chord), the Lithuanian composer Julius Juzeliūnas (1916–2001)

2 In previous research conducted by the author of this article, including the study into interval distances in Lithuanian folk music scales compared to natural harmonic series and 12-TET (2022), tones that refer to the microtones or to natural intervals or to the tuning of just intonation were identified which can reach up to 11 harmonics (Nos. 3, 5, 9, and 11) in wooden trumpet ensembles and vocal multi-part *sutartinės* chants, proving the prevalence of microtonal structures and examples of natural tunings in the Lithuanian folk music tradition (Germanavičius 2022).

3 The composer and conductor Jeronimas Kačinskas (1907-2005) is considered to be one of the most prominent modernists of the interwar period in Lithuania. He spent two years at Prague Conservatory, where he took a course in quarter-tone music under Alois Hába, from whom he acquired knowledge of the microtonal and athematic style of music. He adopted an individual approach to microtonality in a number of his works written in the thirties, which became first examples of avant-garde music in Lithuania. In 1933, Kačinskas established classes of microtonal music in Kaunas and Klaipėda, and he regularly published articles on microtonal music in the magazine *Muzikos barai* (Fields of Music). Kačinskas's *Nonet* was premiered in 1938 at the International Society for Contemporary Music Festival in London alongside premieres of works by Béla Bartók and Olivier Messiaen; however, most of his microtonal works were lost during the Second World War. After emigrating to the USA, in 1967–1986, he taught composition and conducting at Berklee College of Music in Boston. 'Alois Hába considered Kačinskas's *Nonet* one of the prime examples of modern music composed in the 1930s and repeatedly showcased the work in concerts representing his school in various European countries' (Stanevičiūtė 2020: 289–290). Referring to Kačinskas's Concerto for Trumpet and Orchestra, Hába wrote that the Lithuanian composer 'builds [quartertone] harmonies in a completely distinct way, and his work is characterised by combined rhythms and polyphonic figurations rich in quintuplets and septuplets' (Hába 1931: 3).

4 Kačinskas 1932: 102.

5 Čiurlionytė 1940: 100.

6 Četkauskaitė 2007: 7–8.

7 Venckus 1969: 68–78.

juxtaposes two *sutartinės* at the end of chapter 3, in which he distinguishes augmented and diminished intervals of a *fourth*,[8] which may correspond to harmonics No. 11 and No. 21 of the natural harmonic series.[9]

A study into the psychoacoustics and tonal hierarchies in Lithuanian folk scales was recently conducted by Rytis Ambrazevičius. Having analysed close to a hundred of audio recordings of Lithuanian folk songs and *sutartinė* chants, Ambrazevičius concluded: 'None of the samples resembles 12-TET, i.e., its diatonic subsets including the minor and major versions and other diatonic scales (e.g., the so-called Ancient Greek or Gregorian modes)'.[10]

A review of studies into Lithuanian folk melodies suggests that the aspects of intervals, i.e., distances in the scales, and tuning have not been studied in detail.

Various traditional music tuning systems are based on one of two primary factors: they are grounded either in logic or tradition (i.e., tuning instruments by ear). In the latter case, memory plays a dominant role in societies, musical information is passed down from generation to generation. This may explain the differences in interval tuning observed within the same culture. For example, in Persian music, the distances between natural seconds and thirds can coincide (depending on the performers) and are equal to 45 cents.[11] In Arabic and Persian music, the interval of the natural second ranges between 125 and 170 cents, and the natural third between 325 and 370 cents.[12]

When tuning is based on the natural harmonic series, the number of tones produced by the alphorn is determined by the length of the instrument, which has no holes or valves to fix the pitch. The alphorn produces microtonal harmonics of the harmonic series, such as the 7th, 11th, 13th, and 14th, without using a mouthpiece. Historically, the length of the alphorn changed from shorter to longer in the modern era, so the entire harmonic series played from the fundamental pitch in the highest frequency register was critical and technically complex in earlier centuries. The main keys of modern alphorns are F♯ (length about 3.4 m) or F (length about 3.6 m), and the range of tones produced reaches from the 2nd to the 12th harmonic, although virtuoso performers often extend the spectrum of the harmonic series up to the 16th harmonic.[13]

The tuning practices of traditional musical systems frequently diverge from theoretical tuning concepts, reflecting variations shaped by aural tradition, intuitive selection, or modifications of interval sound qualities. These practices give rise to distinctive instrument tunings that contribute to the rich sonic diversity characteristic of traditional cultures. This diversity is influenced, in part, by psychoacoustic

8 Juzeliūnas 1972: 55.
9 Germanavičius 2024: 112.
10 Ambrazevičius 2009: 13.
11 Farhat 2009: 26.
12 Chahin 2017: 15.
13 Wey, Kammermann 2020: 67.

phenomena related to sound perception, the ongoing exploration of alternative tunings by composers and performers, and the impact of contemporary technological environments on the evolution of the tradition itself.

The main goal of this study was to compare Lithuanian folk scales with the historical tuning systems of Europe and the Middle East to determine the tuning or temperament characteristic of Lithuanian traditional music. Another goal of this study was to determine the tuning system that is closest to the tuning of each song and to set up a tuning that is common for all songs, as well as to compare the audio recordings of Lithuanian immigrant songs in the USA with those in Lithuania to see if they have any differences in tuning and intonation.

It was hypothesised that the European tuning systems of the sixteenth to the twentieth centuries (meantone and irregular well temperaments) may have influenced Lithuanian folk music and its tuning system through the spread of Christian music (especially organ music) coming to Lithuania from Italy and Germany, and that, on the other hand, perhaps Lithuanian folk music may have been influenced by the music of the non-Christian cultures of Karaims, Crimean Tatars, and Jews, who had been living in Lithuania since the Middle Ages.

Therefore, the Lithuanian folk scales of the first half of the twentieth century were chosen for comparison as they are likely to have preserved the earlier tunings both in Lithuania and the USA. The research material was collected from the Lithuanian Folklore Archive's Database[14] of the Institute of Lithuanian Literature and Folklore in Vilnius; a total of 513 samples recorded between 1930 and 1940 were reviewed and analysed using the Melodyne software. Based on the criteria for comparison with historical temperaments, ninety-five samples were selected for further analysis: four *kanklės* recordings, five *skudučiai* (panpipes), sixteen wooden trumpet ensembles, thirty-five monodic songs, and thirty-five *sutartinės* (traditional multipart songs).

Thirteen out of 20 samples were selected for comparative analysis with historical temperaments from the Smithsonian Folkways Collection[15] in Washington D.C. These recordings were made in the United States between 1949 and 1950.

A list of the Shellac Collection[16] records of the Lithuanian Culture Museum in Chicago and the Lithuanian Research Center in Lemont was obtained from the Martynas Mažvydas National Library, comprising 2,575 samples of various music genres of both pre-war and post-war periods. From these, 93 samples of traditional Lithuanian songs and instrumental music, dated between 1908 and 1940, were selected. After listening and initial screening, 35 samples showing potential deviations from equal temperament were selected for computer-assisted analysis. Following the study of

14 Lithuanian Folklore Archive's Database, https://irasai.archyvas.llti.lt/?lang=en [2025 09 30].

15 Lithuanian Folk Songs in the United States, https://folkways.si.edu/lithuanian-folk-songs-in-the-united-states/american-folk-world/music/album/smithsonian [accessed 2025 09 30].

16 ePaveldas, https://www.epaveldas.lt/main [accessed 2025 09 30].

the scales, ten samples were chosen for comparative analysis with historical temperaments. These recordings were made in the United States between 1910 and 1929. The total of 118 samples selected for comparative analysis.

Instrumental music recordings are evidently far less common than vocal samples. For example, wooden trumpet ensembles have been analysed three times less frequently than vocal *sutartinės*, while *skudučiai* (panpipes) and *kanklės* (Baltic psaltery) have been studied five and ten times less, respectively. This discrepancy is largely due to the quality and availability of archival recordings: only a small number of high-quality recordings and performances have been preserved, and many recordings have been lost entirely. In horn ensembles (also known as wooden trumpets), instruments are typically tuned with fixed pitch, in contrast to *kanklės* and *skudučiai*, which allows for variable tuning in each performance. Similarly, in vocal music, singers often modulate their voices and improvise, subtly altering interval distances through timbral shifts. Audio analyses further reveal that the same ensemble may perform the same song with microtonal variations in pitch distribution. Thus, the decision was taken that a tone would be considered a microtone when calculating from the fundamental tone of the scale with a deviation of between 20–80 cents compared to the equal temperament system, and that overtones could be defined as a characteristic deviation of up to 10–25 cents compared to the interval relations of the natural harmonic series.

Since old recordings may contain some temporal deviations from the original performances, it is worth mentioning research conducted by scholars analysing interpretation issues among both professional and non-professional performers:

Given the described implementations of pitch scatter and formant smear in syntheses of unison choir sounds, the present experiment showed that – on the average, experienced listeners preferred pitch scatter to be between 0 and 5 cents and would tolerate scatter between 10 and 15 cents.[17]

For temperings of about 20–30 cents, musically trained subjects consistently identified the direction in which the size of fifths and major thirds was changed.[18]

We have no direct test on the fifths, but the degree of asymmetry in our curves for thirds and sixths indicates that this identification clearly occurs already in the 20–30 cents range in most cases, and often by about 15 cents.[19]

When analysing old recordings, it is essential to distinguish between artifacts introduced by recording technology, such as temporal and pitch deviations, and the natural interpretative variations introduced by non-professional performers. Research on pitch perception and interval recognition suggests that while trained listeners are sensitive to pitch deviations as small as 15–30 cents, such variations typically do not alter the fun-

17 Ternström 1991: 48.

18 Vos 1986: 234.

19 Hall, Hess 1984: 191.

damental perception of musical intervals. Similarly, performance-based deviations in interval amplitude arising from expressive intent or ensemble tuning tend to remain within perceptual thresholds that preserve the categorical identity of intervals such as fifths and thirds. Therefore, although both recording-related and performance-related deviations exist, the magnitude of these variations is generally insufficient to compromise the listener's conceptual understanding of interval structure.

In this type of study, the equal temperament system (12-TET) was used as a reference point for describing interval distances. This provided a framework for identifying characteristic microtonal scale degrees and allowed for comparisons with the natural harmonic series and their respective interval distances. When selecting songs for analysis, preference was given to the examples of monodies that exhibited distinct microtonal pitches, and wooden trumpet ensembles with fixed tuning as well as natural intervals in both vocal and instrumental music. This approach enabled the identification and systematic classification of structural features characteristic of archaic scale systems, including the naming of specific microtones and the recognition of typical harmonics. The identification of tone distances in the scale was followed by the rule that if a tone lies near a temperate boundary (12-TET) but is positioned either slightly above a lower harmonic or below a higher one, thus deviating further from the tempered pitch, the resulting tone is considered to correspond to the harmonic. In other cases, when a tone lies both near a harmonic and close to a 12-TET pitch boundary, and the deviation from the harmonic is within 1–2 cents, the tone may be interpreted as aligning with either the harmonic or the tempered pitch. However, in order to reliably determine tuning according to the overtone series, at least one primary natural interval, such as a pure fifth, a fourth, or a third, must be clearly dominant. This criterion allows for accurate identification of tuning systems based on the natural harmonic series, thereby excluding the 12-TET reference in both vocal and instrumental music examples. Furthermore, tones that deviate from a particular natural harmonic by approximately 20–30 cents may still be attributed to that harmonic, thereby maintaining the structure of tuning based on the natural overtone series.

A question was raised whether the music of non-Christian communities in Lithuania could have influenced Lithuanian folk music. Unfortunately, only two or three surviving audio recordings of Karaim traditional music, mainly religious and ceremonial songs (e.g., a wedding song), exist. A similar situation was true for the music of the Crimean Tatars living in Lithuania. Regarding Lithuanian Jewish folk music prior to 1940, most of the recordings were dominated by religious or klezmer music, and there are no surviving recordings of other genres in Lithuania.

The material for the study of Lithuanian folk songs was taken mainly from the author's doctoral dissertation (2022), including the completed analyses of the scales; in addition, a study into American Lithuanian folk scales was conducted using computer audio file analysis and the editing programme Melodyne, determining interval

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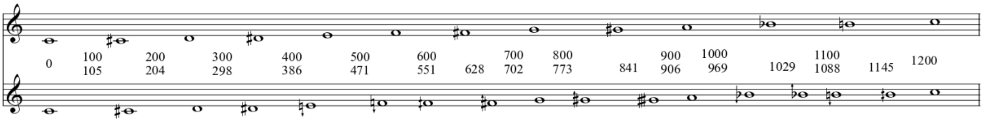
distances in order to compare them with 13 historical temperament systems:[20] the medieval Pythagorean, five meantone temperaments, four well-temperaments, the al Farabi (Arabic) scale, as well as the scale of natural harmonic series and the 12-tone equal temperament (Fig. 1). The historical temperaments were chosen to determine the influence of their tuning on folk music at the beginning of the twentieth century and to determine the similarity of the intervals of the song to one or another tuning.

12-TET and Natural Harmonic Series



Al-Farabi Scale (Arabic)

Ratio	**1/1**	**256/243**	**18/17**	**162/149**	**54/49**	**9/8**	**32/27**	**81/68**	**27/22**	**81/64**	**4/3**	**3/2**	**18/11**	**16/9**	**2/1**
Scale	C					D				E♭	F	G	A	B♭	C
Cents	0	90	98	145	168	204	294	303	355	408	498	702	853	996	1200

Pythagorean Scale (Middle Ages)

Scale	C	C#	D	E♭	E	F	F#	G	G#	A	B♭	B	C
Ratio	1:1	256:243	9:8	32:27	81:64	4:3	729:512	3:2	128:16	27:16	16:9	243:128	2:1
Cents	0	90.22	203.9	294.1	407.8	498	611.7	702	792.2	905.9	996.1	1109.8	1200

Meantone temperaments:

Pietro Aron ¼ comma temperament (the sixteenth century)

Scale	**C**	**C#**	**D**	**E♭**	**E**	**F**	**F#**	**G**	**G#**	**A**	**♭**	**B**	**C**
Cents	0	76	193	310	386	503	579	697	773	890	1007	1083	1200

Fig. 1. Historical tunings from the Middle Ages (the sixteenth to the twentieth centuries)[21], including natural harmonic series[22], are arranged in the chromatic scale (except the Arabic scale)[23] with interval ratio and distances calculated in cents

20 'Historical' refers to eleven temperaments; the other two are tuning of just intonation and 12-TET. A system of tuning differentiated from just intonation in which the size of intervals is varied from pure by small amounts, usually to avoid a redundancy of pitches inconveniently close together. Theoretically, the intervals of a temperament are considered irrational ratios. In historical practice, temperament was often achieved intuitively and without exactitude. In modern experimental tunings, the word 'temperament' is often encountered in the concept of equal temperaments of more or fewer than twelve pitches (Gann 2019: 282).

21 Gann 2019: 49, 92; Barbour 1951: 26–42.

22 Germanavičius 2024: 17.

23 Abddon 2003: 4.

Fig. 1. (continued)

Gioseffo Zarlino 2/7 comma temperament (the sixteenth century)

Scale	**C**	**C#**	**D**	**E♭**	**E**	**F**	**F#**	**G**	**G#**	**A**	**B♭**	**B**	**C**
Cents	0	70	191	313	383	504	574	696	817	887	1008	1078	1200

Francisco de Salinas 1/3 comma temperament (the sixteenth century)

Scale	**C**	**C#**	**D**	**E♭**	**E**	**F**	**F#**	**G**	**G#**	**A**	**B♭**	**B**	**C**
Cents	0	64	190	316	379	505	569	695	758	884	1010	1074	1200

Rossi 2/9 comma temperament (the seventeenth century)

Scale	C	C#	D	E♭	E	F	F#	G	G#	A	B♭	B	C
Cents	0	79	194	308	389	503	582	697	777	892	1006	1085	1200

Silbermann 1/6 comma temperament (the eighteenth century)

Scale	**C**	**C#**	**D**	**E♭**	**E**	**F**	**F#**	**G**	**G#**	**A**	**B♭**	**B**	**C**
Cents	0	89	197	305	394	502	590	698	787	895	1003	1092	1200

Well temperaments:

Andreas Werckmeister III (1691)

Scale	**C**	**C#**	**D**	**E♭**	**E**	**F**	**F#**	**G**	**G#**	**A**	**B♭**	**B**	**C**
Cents	0	90.225	192.18	294.135	390.225	498.045	588.27	696.18	792.18	888.27	996.09	1092.18	1200

Thomas Young (1799)

Scale	**C**	**C#**	**D**	**E♭**	**E**	**F**	**F#**	**G**	**G#**	**A**	**B♭**	**B**	**C**
Cents	0	93.9	195.8	297.8	391.7	499.9	591.9	697.9	795.8	893.8	999.8	1091.8	1200

Antonio Vallotti (1779)

Scale	**C**	**C#**	**D**	**E♭**	**E**	**F**	**F#**	**G**	**G#**	**A**	**B♭**	**B**	**C**
Cents	0	94.1	196.1	298	392.2	501.96	592.2	698	796.1	894.1	1000	1090.2	1200

Johann Neidhardt (1724)

Scale	**C**	**C#**	**D**	**E♭**	**E**	**F**	**F#**	**G**	**G#**	**A**	**B♭**	**B**	**C**
Cents	0	94.2	198	296.2	390.2	498.2	592.2	700	794.2	894.1	998.2	1092.2	1200

Research Formula and Pitch Distance Calculation

Before starting the research, the AI Excellence Centre of at the Kaunas University of Technology was contacted to explore the possibility of applying AI-based method in the study. While the use of an AI method was technically feasible, the limited amount of available data (many of the audio recordings were lost during the Second World War), ultimately led to the decision to proceed with conventional computer-based statistical analysis. As a result, the mathematician Dr Mindaugas Kavaliauskas agreed to develop a research formula that could be applied in the statistical analysis software R to conduct a comparative study. The following pages will explain what the research formula consists of and how the comparison of scales with temperaments was calculated.

$$D(i,k) = \frac{1}{n_i} \sum_{j=1}^{n_i} d(s_{ij}, k).$$

Fig. 2. The research formula marks the song, pitch, temperament number, and distance. The number of pitches used in the song and the temperament are defined by the subtraction process followed by addition and division operations

In the brackets (Fig. 2), the letter marks a song, then marks a song number (first, second and etc. 1, 2, 3, ... 118), s_j marks pitch number of the selected song in the scale, and n_i number of pitches used in the song. Let s_{ij}, where $i = 1, \ldots j = 1, \ldots, n_i$ denote the pitch in cents (hundredths of a semitone) of the j-th pitch of the i-th song. Here, the number of songs analysed $n = 118$, and n_i is the number of pitches used in the i-th song, which varied between three and seven in the different songs. The table in Fig. 3 shows the analysis of the first four songs.

No. of song., No. of pitch Distances Number of pitches	$s_{1,1}$ 0	$s_{1,2}$ 204	$s_{1,3}$ 386	$s_{1,4}$ 495	$s_{1,5}$ 568	$n_1 = 5$
	$s_{2,1}$ 0	$s_{2,2}$ 257	$s_{2,3}$ 409	$s_{2,4}$ 563		$n_2 = 4$
	$s_{3,1}$ 0	$s_{3,2}$ 187	$s_{3,3}$ 376	$s_{3,4}$ 485		$n_3 = 4$
	$s_{4,1}$ 0	$s_{4,2}$ 142	$s_{4,3}$ 345	$s_{4,4}$ 520	$s_{4,5}$ 651	$n_4 = 5$
	$s_{118,1}$					

Fig. 3. Analysis of four songs. The scales of four songs are displayed in a row of four and five pitches, each marked by the interval distance in cents from the fundamental

Similarly with the temperaments, Figure 4 shows that f marks a temperament, then f_k marks the number of the temperament (first, second ... 1, 2, 3, ... 13), f_l is pitch number in the scale of the selected temperament, and number of pitches used in the temperament. Let us take the letter f_{kl}, where $k = 1, \ldots m$, $l = 1, \ldots, m_k$ denotes the pitch in cents (hundredths of a semitone) of the l-th pitch of the k-th temperament. Here m = 13 is the number of temperaments used in the analysis, and m_k is the number of pitches used in the k-th temperament, which is usually equal to 12, but can take other values, e.g. equal to 14 pitches in the Arabic scale.

Temperament	**N / A**				**Comma**					**Well**			
Tuning	Pyth.	Arab.	Nat.	12-tet	1/4	2/7	1/3	2/9	1/6	Werck.	Young	Valotti	Neihardt
Temp. No., Pitch No. Distance	$f_{1,1}$ 0	$f_{2,1}$ 0	$f_{3,1}$ 0	$f_{4,1}$ 0	$f_{5,1}$ 0	$f_{6,1}$ 0	$f_{7,1}$ 0	$f_{8,1}$ 0	$f_{9,1}$ 0	$f_{10,1}$ 0	$f_{11,1}$ 0	$f_{12,1}$ 0	$f_{13,1}$ 0
	$f_{1,2}$ 90.22	$f_{2,2}$ 90	$f_{3,2}$ 105	$f_{4,2}$ 100	$f_{5,2}$ 76	$f_{6,2}$ 70	$f_{7,2}$ 64	$f_{8,2}$ 79	$f_{9,2}$ 89	$f_{10,2}$ 90.225	$f_{11,2}$ 93.9	$f_{12,2}$ 94.1	$f_{13,2}$ 94.2
		$f_{2,3}$ 98											
		$f_{2,4}$ 145											
		$f_{2,5}$ 168											
	$f_{1,3}$ 203.9	$f_{2,6}$ 204	$f_{3,3}$ 204	$f_{4,3}$ 200	$f_{5,3}$ 193	$f_{6,3}$ 191	$f_{7,3}$ 190	$f_{8,3}$ 194	$f_{9,3}$ 197	$f_{10,3}$ 192.18	$f_{11,3}$ 195.8	$f_{12,3}$ 196.1	$f_{13,3}$ 198
	$f_{1,4}$ 294.1	$f_{2,7}$ 294	$f_{3,4}$ 298	$f_{4,4}$ 300	$f_{5,4}$ 310	$f_{6,4}$ 313	$f_{7,4}$ 316	$f_{8,4}$ 308	$f_{9,4}$ 305	$f_{10,4}$ 294.135	$f_{11,4}$ 297.8	$f_{12,4}$ 298	$f_{13,4}$ 296.2
		$f_{2,8}$ 303											
		$f_{2,9}$ 355											
	$f_{1,5}$ 407.8	$f_{2,10}$ 408	$f_{3,5}$ 386	$f_{4,5}$ 400	$f_{5,5}$ 386	$f_{6,5}$ 383	$f_{7,5}$ 379	$f_{8,5}$ 389	$f_{9,5}$ 394	$f_{10,5}$ 390.225	$f_{11,5}$ 391.7	$f_{12,5}$ 392.2	$f_{13,5}$ 390.2
	$f_{1,6}$ 498	$f_{2,11}$ 498	$f_{3,6}$ 471	$f_{4,6}$ 500	$f_{5,6}$ 503	$f_{6,6}$ 504	$f_{7,6}$ 505	$f_{8,6}$ 503	$f_{9,6}$ 502	$f_{10,6}$ 498.045	$f_{11,6}$ 499.9	$f_{12,6}$ 501.96	$f_{13,6}$ 498.2
	$f_{1,7}$ 611.7		$f_{3,7}$ 551	$f_{4,7}$ 600	$f_{5,7}$ 579	$f_{6,7}$ 574	$f_{7,7}$ 569	$f_{8,7}$ 582	$f_{9,7}$ 590	$f_{10,7}$ 588.27	$f_{11,7}$ 591.9	$f_{12,7}$ 592.2	$f_{13,7}$ 592.2
			$f_{3,8}$ 628										
	$f_{1,8}$ 702	$f_{2,12}$ 702	$f_{3,9}$ 702	$f_{4,8}$ 700	$f_{5,8}$ 697	$f_{6,8}$ 696	$f_{7,8}$ 695	$f_{8,8}$ 697	$f_{9,8}$ 698	$f_{10,8}$ 696.09	$f_{11,8}$ 697.9	$f_{12,8}$ 698	$f_{13,8}$ 700
	$f_{1,9}$ 792.2		$f_{3,10}$ 773	$f_{4,9}$ 800	$f_{5,9}$ 773	$f_{6,9}$ 817	$f_{7,9}$ 758	$f_{8,9}$ 777	$f_{9,9}$ 787	$f_{10,9}$ 792,18	$f_{11,9}$ 795,8	$f_{12,9}$ 796,1	$f_{13,9}$ 794,2
			$f_{3,11}$ 841										
	$f_{1,10}$ 905.9	$f_{2,13}$ 853	$f_{3,12}$ 906	$f_{4,10}$ 900	$f_{5,10}$ 890	$f_{6,10}$ 887	$f_{7,10}$ 884	$f_{8,10}$ 892	$f_{9,10}$ 895	$f_{10,10}$ 888,27	$f_{11,10}$ 893.8	$f_{12,10}$ 894.1	$f_{13,10}$ 894.1

Fig. 4. Analysis of 13 temperaments. The 13 temperaments are displayed in a row of 12 pitches, except the Arabic and natural tunings, which have 14 and 16 pitches respectively, marked by the interval distance in cents from the fundamental

Fig. 4. (continued)

Temperament	**N / A**				**Comma**					**Well**			
Tuning	Pyth.	Arab.	Nat.	12-tet	1/4	2/7	1/3	2/9	1/6	Werck.	Young	Valotti	Neihardt
	$f_{1,11}$ 996.1	$f_{2,14}$ 996	$f_{3,13}$ 969	$f_{4,11}$ 1000	$f_{5,11}$ 1007	$f_{6,11}$ 1008	$f_{7,11}$ 1010	$f_{8,11}$ 1006	$f_{9,11}$ 1003	$f_{10,11}$ 996.09	$f_{11,11}$ 999.8	$f_{12,11}$ 1000	$f_{13,11}$ 998.2
			$f_{3,14}$ 1029										
	$f_{1,12}$ 1109.8		$f_{3,15}$ 1088	$f_{4,12}$ 1100	$f_{5,12}$ 1083	$f_{6,12}$ 1078	$f_{7,12}$ 1074	$f_{8,12}$ 1085	$f_{9,12}$ 1092	$f_{10,12}$ 1092.18	$f_{11,12}$ 1091.8	$f_{12,12}$ 1090.2	$f_{13,12}$ 1092.2
			$f_{3,16}$ 1145										
No. of pitches $m_k =$	12	14	16	12	12	12	12	12	12	12	12	12	12

Since the pitches of both the songs and the temperaments are expressed in cents, their similarity can be defined as the modulus of the difference. Then, searching for an equivalent of the distance of the pitch s_{ij} of the song in the temperament of k, the pitch with the minimum or equal distance is calculated in cents. In this way, the distance between a pitch in the scale and its equivalent in the temperament (the deviation of the note) is defined by the subtraction formula:

$$d(s_{ij},k) = \min_{l=1,\ldots,m_k} | s_{ij} - f_{kl} | .$$

Fig. 5. Distance between a pitch in the scale and its equivalent in the temperament as defined by the subtraction formula

Looking at the formula above (Fig. 5), d, distance (s_i – song number, s_j – pitch number, and k – temperament number) equals minimum l = 1 pitch number, m_k being the number of pitches. For example, let us take the distance number of the fourth song with the pitch number two (see Fig. 3, analysis of the songs). S4,1 song in the table, S4,2 second pitch in the scale=142 cents, this pitch is calculated with the distance numbers for example of Pythagorean temperament k1 from the list (see Fig. 4, analysis of the temperaments). In the table Pythagorean is No. 1 from top to bottom, in the first row.

Now see the subtraction formula and the results (Fig. 6). One pitch from the song is compared to all the pitches of the selected temperament. Subtracting the pitch distance of the selected temperament from the single pitch distance of the song gives the result. Then the smallest possible number is taken, which is 52 cents.

Formula $d(s_{4,1}, \text{k1}) = \min\{|142\text{-}0|, |142\text{-}90{,}22|, |142\text{-}203{,}9|, |142\text{-}294{,}1|, |142\text{-}407{,}8|,....|142\text{-}1200|\} = |142\ |52|62|152|266|.....|1058|$.

Fig. 6. Subtracting the pitch distance of the temperament from the single pitch distance of the song

$s_{ij} - f_{kl}$ = 52 cents or $d(s_{42}, k1)$ = 52 cents is a minimum interval distance in the song to compare with the interval distance in the temperament. Then, in this way every next pitch of the song is calculated with the pitch distances of the temperament (Fig. 7):

$$d(s_{43}, k1) = d(345, 1) = \ldots = 51 \text{ cents}.$$

Fig. 7. Calculating tone distances. Subtracting every pitch of the song from the pitch distances of the temperament

The minimum interval distance of the song S4 pitch 3 and temperament $k1$ equals 51 cents. Then the distance between the pitches of the song and the temperament is defined as the average distance between the pitches of the song in the scale and the pitches of the selected temperament, i.e.:

$$D(4,1) = \frac{1}{5}\sum_{j=1}^{n_i} d(s_{41},1) + d(s_{42},1) + d(s_{43},1) + d(s_{44},1) + d(s_{45},1) =$$

$$= \frac{1}{5}(0 + 52 + 51 + 22 + 40) = \frac{165}{5} = 33ct$$

Fig. 8. Calculation of one song with Pythagorean tuning. Calculating pitch distances with Pythagorean tuning by subtracting the pitches of the song from the pitches of the temperament and dividing the resulting sum by five (the tones of the song)

Figure 8 presents the results of the previous calculation of the song. Now adding each pitch shows how close the scale of the song is to the Pythagorean tuning; the result is 33 cents. Then the distances of the same song with the next 12 temperaments are calculated (Fig. 9):

$$D(i = 4, k = 2) = \ldots$$

$$D(i = 4, k = 3) =$$

$$D(i = 4, k = 4) =$$

$$\ldots\ldots\ldots\ldots$$

$$D(i = 4, k = 13) =$$

Fig. 9. Calculation of the song with 13 temperaments. Calculating pitch distances of the song compared to 13 temperaments indicates the temperament of the song

The value for which the distance $D(i, k)$ for the i-th song is smallest indicates the temperament of this song. The differences in the pitch distances between the determined temperaments are analysed for different groups of songs.

Calculation of Distances of Song Intervals to 12-TET

The calculation for the song (FW04009_19.flac) will be shown in comparison with the 12-TET. The recording is from the Smithsonian Folkways Discography Collection. The song has four notes with frequencies expressed in cents:

Scale A B C# D
Distances 0 200 394 467.

Fig. 10. Folk song analysis (recorded in the USA). The folk song analysis compared to the 12-TET indicates the interval distances of the scale in cents, song FW04009_19.flac (Smithsonian Folkways Discography Collection, USA)

In this case the 12-TET temperament is defined by 13 pitches (including tonic or the interval of an octave):
12-TET Scale – 0, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200.

The distance of this song to the 12-TET tuning will be calculated. This starts by calculating the distance between the first note of the song (equal to 0 cents) and each note of 12-TET. The result is trivial in this case, but the detailed calculations are as follows:

First pitch |0-0|=0, |0-100|=100, |0-200|=200, |0-300|=300, |0-400|=0, |0-500|=500, |0-600|=600, |0-700|=700, |0-800|=800, |0-900|=900, |0-1000|=1000, |0-1100|=1100, |0-1200|=1200.

The **first** note of the song (0 cents) is the most similar to the **first** note of the temperament (0 cents) with a distance of 0, because
min (0, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200)=0.

Let us calculate the distance between the **second** note of the song (equal to 200 cents) and each note of 12-TET.

Second pitch |200-0|=200, |200-100|=100, |200-200|=0, |200-300|=100, |200-400|=200, |200-500|=300, |200-600|=400, |200-700|=500, |200-800|=600, |200-900|=700, |200-1000|=800, |200-1100|=900, |200-1200|=1000.

The **second** note of the song (200 cents) is the most similar to the **third** note of the temperament (200 cents) with a distance of 0, because min(200, 100, 0, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000)=0.

The distance between the **third** note of the song (equal to 394 cents) and each note of 12-TET is then calculated.

Third pitch |394-0|=394, |394-100|=294, |394-200|=194, |394-300|=94, |394-400|=6, |394-500|=106, |394-600|=206, |394-700|=306, |394-800|=406, |394-900|=506, |394-1000|=606, |394-1100|=706, |394-1200|=806.

The **third** note of the song (394 cents) is the most similar to the **fifth** note of the temperament (400 cents) with a distance of 6, because
min(394, 294, 194, 94, 6, 106, 206, 306, 406, 506, 606, 706, 806)=6.

Finally, let the calculations be repeated for the **fourth** and the last note of the song (which is equal to 467 cents). Distances to each note of 12-TET are:

Fourth pitch |467-0|=467, |467-100|=367, |467-200|=267, |467-300|=167, |467400|=67, |467-500|=33, |467-600|=133, |467-700|=233, |467-800|=333, |467-900|=433, |467-1000|=533, |467-1100|=633, |467-1200|=733.

The **fourth** note of the song (467 cents) is the most similar to the **sixth** note of the temperament (500 cents) with a distance of 33 cents. Now the distances for the four notes of the song have been obtained: 0, 0, 6, 33, then (0 + 0 + 6 + 33) / 4 = 9.75 ct. The average of these 'errors' is the distance between the song and 12-tone equal temperament (equal to 9.75 cents).

Calculation of Distances of Song Intervals to Natural Tuning

Next a calculation of the same song to natural tuning will be demonstrated. Natural tuning is defined by other distances and 17 pitches (including tonic or the interval of an octave):

0, 105, 204, 298, 386, 471, 551, 628, 702, 773, 841, 906, 969, 1029, 1088, 1145, 1200 cents.

A shorter description of the calculation will be given, skipping the detailed calculations of each note of the song to each note of the tuning.

Scale	A	B	C#	D
Distances	0	200	394	467

Fig. 11. Distance to natural tuning calculation indicates the interval distances of the scale in cents, song FW04009_19.flac (Smithsonian Folkways Discography Collection, USA)

The 0 cents note of the song is the most similar to the 0 cents note of the tuning and the distance is |0-0|=0.

The 200 cents note of the song is the most similar to the 204 cents note of the tuning and the distance is |200-204|=4.

The 394 cents note of the song is the most similar to the 386 cents note of the tuning and the distance is |394-386|=8.

The 467 cents note of the song is the most similar to 471 cents note of the tuning and the distance is |467-471|=4.

Then all the results are totalled and divided by four to calculate the distance: (0 + 4 + 8 + 4) / 4 = 4. The distance between the tuning of the song and natural tuning is four cents. It is clear that the notes of the song are closer to natural tuning (with an average distance of four) than to the 12-TET tuning (with an average distance of 9.75). By repeating the same approach, the interval distances of the song to the remaining tunings are calculated. The obtained values are:

distance to Pythagorean tuning is 12.175,
distance to Arabic tuning is 12.25,
distance to natural tuning is 4,
distance to 12-TET is 9.75,
distance to 1/4 comma temperament is 12.75,
distance to 2/7 comma temperament is 14.25,
distance to 1/3 comma temperament is 15.75,
distance to 2/9 comma temperament is 11.75,
distance to 1/6 comma temperament is 9.5,
distance to Werckmeister III temperament is 10.66,
distance to Young temperament is 9.85,
distance to Vallotti temperament is 10.165,
distance to Neidhardt temperament is 9.25

Fig. 12. Distance to other tunings calculation and tuning selection by setting the minimum distance of the scale to the temperament, song FW04009_19.flac (Smithsonian Folkways Discography Collection, USA)

The shortest distance, i.e., the best tuning match for this song, is to the previously calculated natural tuning, which is four cents. So, the assumption can be made that natural tuning is used in this song.

The research formula was first used to compare the interval distances of all 118 song pitches to the 13 temperament systems. The table in Figure 13 summarises all the research material and shows the closest temperament or tuning for each song scale. For example, a selected row shows a song, the closest distance for each temperament, and the result (including song archive number, song group and country, song scale, pitch distances, scale degrees, and transposed scale from C).

	Name	Group	pitch1	pitch2	pitch3	pitch4	pitch5	pitch6	pitch7	cts1	cts2	cts3	cts4	cts5	cts6	cts7	degree1	degree2	degree3	degree4	degree5	degree6	degree7	scale
1	ltrf,pl,610,8	**Sutartinė**	A	B	D♭	D	E♭			0.0	204	386	495	568			I	II	III	IV	V			1/4 comma
2	ltrf,pl,279,3	Sutartinė	A	C	D	E♭				0.0	257	409	563				I	III	III	IV				Natural
3	ltrf,pl424,1b	Sutartinė	C	D	E	F				0.0	187	376	485				I	II	III	IV				1/3 comma
4	ltrf,pl424,1a	Sutartinė	B	C	D	E	F			0.0	142	345	520	651			I	II	III	IV	V			Arabic
5	ltrf,pl189b1	Sutartinė	G♭	A	B♭	C	D♭			0.0	246	386	559	702			I	II	III	IV	V			Natural
6	CD32	Sutartinė	A♭	B♭	C	D♭	E♭			0.0	178	362	482	713			I	II	III	IV	V			Arabic
7	ltrfpl614,9	Sutartinė	A♭	B♭	C	D♭	E♭			0.0	207	436	553	774			I	II	III	IV	V			Natural
8	ltrf,pl614,10	Sutartinė	G#	A	B♭	C	D	D#		0.0	136	325	455	662	711		I	II	III	III	IV	V		Natural
9	ltrf,pl420,1a	Sutartinė	C	C#	D	E	F			0.0	49	199	395	497			I	II	II	III	IV			2/9 comma
10	ltrf,pl420,1b	Sutartinė	C	C#	D	D#	E	F		0.0	98	236	283	446	555		I	II	II	III	III	IV		Natural
11	CD61	Sutartinė	C	D♭	D	F				0.0	79	209	525				I	II	III	IV				2/9 comma
12	ltrf,pl1059,4	Sutartinė	C	C#	D	E	F			0.0	98	211	438	546			I	II	II	III	IV			Natural
13	CD33	Sutartinė	C	D	E	F				0.0	189	354	482				I	II	III	IV				Arabic
14	ltrf,pl423,1a	Sutartinė	D♭	E♭	F	G♭				0.0	196	352	475				I	II	III	IV				Arabic
15	ltrf,pl,423,1b	Sutartinė	D♭	E♭	F	G♭				0.0	200	367	502				I	II	III	IV				Arabic
16	CD40	Sutartinė	D♭	E♭	F	G♭	A♭	A♭		0.0	260	437	532	703	742		I	II	III	IV	V	VI		Natural
17	ltrf,pl421,1b	Sutartinė	D♭	E♭	F	G♭	A♭			0.0	187	367	469	690			I	II	III	IV	V			Natural
18	ltrf,pl421,1a	Sutartinė	D♭	E♭	F	G♭	A♭			0.0	187	367	469	690			I	II	III	IV	V			Natural
19	ltrf,pl1058,8	Sutartinė	C#	D	F	F#				0.0	149	371	505				I	II	III	IV				Arabic
20	ltrf,pl739,4	Sutartinė	G	A	B	C				0.0	176	376	460				I	II	III	IV				Natural
21	CD9	Sutartinė	G	A♭	B♭	C	D	E♭		0.0	142	335	511	693	847		I	II	III	IV	V	VI		Arabic
22	ltrf,pl187b,5	Sutartinė	G♭	A♭	B♭	B	C	D♭		0.0	235	410	532	580	729		I	II	III	IV	IV	V		2/9 comma
23	ltrfpl,189b,5	Sutartinė	A♭	B♭	C	D	E♭	F		0.0	208	365	558	643	894		I	II	III	IV	IV	VI		Natural
24	CD6	Sutartinė	F#	G#	A	B	C#			0.0	148	331	515	677			I	II	III	IV	V			Arabic
25	ltrfpl,186c,3	Sutartinė	F#	G#	A	B	C#			0.0	169	329	508	673			I	II	III	IV	V			1/3 comma
26	CD36	Sutartinė	A#	C	C#	D#				0.0	179	356	483				I	II	III	IV				Arabic
27	ltrfpl,278,3	Sutartinė	G	G#	A	B	C			0.0	48	227	407	531			I	II	II	III	IV			Arabic
28	CD3	Sutartinė	F	G	A	B♭	C			0.0	167	348	526	689			I	II	III	IV	V			Arabic
29	ltrfpl,186b.6	Sutartinė	F#	G#	A	B	C#			0.0	166	331	517	671			I	II	III	IV	V			1/3 comma
30	CD27	Sutartinė	A	B♭	C	D				0.0	167	375	562				I	II	III	IV				1/3 comma
31	ltrfpl,615,5	Sutartinė	A	B♭	C	D				0.0	182	366	551				I	II	III	IV				1/3 comma
32	ltrfpl,615,6	Sutartinė	G	B♭	C	D				0.0	274	479	664				I	II	IV	V				Natural
33	CD25	Sutartinė	G	A	B♭	C				0.0	164	346	518				I	II	III	IV				Arabic
34	ltrfpl,186c,5	Sutartinė	G#	A	B	C#				0.0	149	334	501				I	II	III	IV				Arabic
35	CD60	Sutartinė	B♭	D♭	E♭	F				0.0	350	496	705				I	III	IV	V				Arabic
36	ltrfpl,547,3	**Monody**	G	A	B	C				0.0	182	379	488				I	II	II	IV				1/3 comma
37	ldda,CD2,19	Monody	F	G	A	B♭	B	C	D	0.0	191	353	478	544	739	928	I	II	III	IV	IV	V	VI	Natural
38	ltrfpl,491,2	Monody	E♭	F	G♭	G	B♭	C		0.0	180	344	416	664	913		I	II	III	III	V	VI		Pythagorean
39	mg1735,44	Monody	F	G	A♭	B♭	C			0.0	184	315	505	705			I	II	III	IV	V			1/3 comma
40	pl,766,6	Monody	C	D♭	E♭					0.0	141	253					I	II	III					Arabic

Fig. 13. Research data and results of 118 songs are displayed by name, group country, scale, pitch distances, scale degrees, followed by the closest result data to the temperament or tuning

	Name	Group	pitch1	pitch2	pitch3	pitch4	pitch5	pitch6	pitch7	cts1	cts2	cts3	cts4	cts5	cts6	cts7	degree1	degree2	degree3	degree4	degree5	degree6	degree7	scale
41	pl,528,3	Monody	A♭	B♭	C	D♭	E♭	F		0.0	212	413	521	708	887		I	II	III	IV	V	VI		Pythagorean
42	pl,579,4	Monody	A	B	C#	D	E	F#		0.0	202	354	517	700	895		I	II	III	IV	V	VI		Neidhardt
43	pl,900,5	Monody	B	C	D	E	F#	G#	A	0.0	87	273	512	710	896	997	I	II	III	IV	V	VI	VII	Pythagorean
44	pl,766,2	Monody	B	C#	D	E				0.0	159	326	451				I	II	III	IV				Arabic
45	pl,1217,3	Monody	G	A	B	D	E	F#		0.0	222	389	728	904	1123		I	II	III	V	VI	VII		Natural
46	lldaCD2,1(36	Monody	C	D	F#	G	A#			0.0	257	633	693	1018			I	II	IV	V	VI			Natural
47	lldacd2,3(38)	Monody	E♭	F	A♭	B♭	B	C		0.0	176	512	685	857	902		I	II	IV	V	VI	VII		1/3 comma
48	pl,1213,6	Monody	C	D	E♭	F	G	A		0.0	174	315	493	673	884		I	II	III	IV	V	VI		1/3 comma
49	pl,1300,2	Monody	E	F#	B	C	C#	D#		0.0	218	698	778	891	1090		I	II	V	VI	VI	VII		2/9 comma
50	mg,1374,15	Monody	B♭	C	D	E♭	F	G♭		0.0	170	371	519	709	855		I	II	III	IV	V	VI		Arabic
51	pl,921,4	Monody	A	A#	C	D	D#	F	G	0.0	134	330	459	632	753	1038	I	II	III	IV	IV	VI	VII	Natural
52	mg,282,68	Monody	C	D♭	F	G♭	G	A♭	B♭	0.0	105	503	576	664	842	1046	I	II	IV	IV	V	VI	VII	Natural
53	pl,576,2	Monody	C	D	E	F				0.0	199	365	481				I	II	III	IV				Arabic
54	pl,33,8	Monody	F#	G#	A	C	C#			0.0	191	323	554	698			I	II	II	IV	V			1/3 comma
55	pl,576,5	Monody	C#	D	E	F#				0.0	151	328	508				I	II	III	IV				Arabic
56	pl,766,5	Monody	B	C	C#	D				0.0	93	152	256				I	II	II	III				Arabic
57	pl,766,4	Monody	C	D♭	E♭					0.0	149	312					I	II	III					Arabic
58	pl,766,7	Monody	C	D	E♭					0.0	156	255					I	II	III					Arabic
59	pl,1220,3	Monody	D	E♭	E	G♭	A♭			0.0	150	261	440	606			I	II	II	III	IV			Pythagorean
60	mg,1617,21	Monody	G♭	A♭	A	B	D♭	D		0.0	169	320	528	714	858		I	II	III	IV	V	VI		Arabic
61	mg,420,2	Monody	C	D	E♭	E				0.0	211	283	441				I	II	III	III				Arabic
62	pl,485,4	Monody	B♭	C	D	E♭				0.0	191	350	471				I	II	III	IV				Arabic
63	mg,42,2	Monody	F	G	A	B♭				0.0	187	367	471				I	II	III	IV				Natural
64	CD32	Monody	E♭	E	A♭	B♭	B	C	D♭	0.0	145	504	693	781	848	1019	I	II	IV	V	VI	VI	VII	Natural
65	pl,27,4	Monody	E♭	E	A♭	A	B♭	B	D♭	0.0	143	498	562	697	781	1017	I	II	IV	IV	V	VI	VII	1/4 comma
66	pl,710,3	Monody	A♭	B♭	C	D♭	E♭	F		0.0	193	374	536	688	877		I	II	III	IV	V	VI		1/3 comma
67	CD31	Monody	B♭	C	D♭	E♭	F	G♭	A♭	0.0	176	347	495	684	785	1006	I	II	III	IV	V	VI	VII	2/9 comma
68	pl,977,3	Monody	F	G♭	B♭	C	D	E♭		0.0	135	514	705	925	1040		I	II	IV	V	VI	VII		Natural
69	mg,454,4	Monody	C	D♭	E♭	F	G	A♭		0.0	131	321	509	677	805		I	II	III	IV	V	VI		12-TET
70	pl,547,3	Monody	G	A	B	C				0.0	182	379	488				I	II	III	IV				1/3 comma
71	CD28	**W.Trumpets**	F	G	A	B	C			0.0	202	355	573	679			I	II	III	IV	V			1/3 comma
72	pl,503,1a	W.Trumpets	F#	G#	A#	B	C#			0.0	201	360	544	690			I	II	III	IV	V			Natural
73	pl,503,1b	W.Trumpets	G♭	A♭	B♭	C	D♭			0.0	201	359	576	679			I	II	III	IV	V			2/7 comma
74	pl,503,1c	W.Trumpets	F	G	A	B	C			0.0	202	366	567	676			I	II	III	IV	V			1/3 comma
75	CD34	W.Trumpets	G♭	A♭	B♭	C	D♭			0.0	204	371	556	652			I	II	III	IV	V			Natural
76	pl,505,2	W.Trumpets	F	G	A	B	C			0.0	192	365	565	681			I	II	III	IV	V			1/3 comma
77	pl,505,3	W.Trumpets	G♭	A♭	B♭	C	D♭			0.0	217	379	578	688			I	II	III	IV	V			1/4 comma
78	CD31	W.Trumpets	G♭	A♭	B♭	C	D♭			0.0	192	365	542	684			I	II	III	IV	V			1/3 comma
79	pl,503,2a	W.Trumpets	F	G	A	B	C			0.0	193	366	546	676			I	II	III	IV	V			1/3 comma
80	pl,503,2b	W.Trumpets	F#	G#	A#	B	C#			0.0	220	374	505	681			I	II	III	IV	V			1/3 comma

Fig. 13. (continued)

	Name	Group	pitch1	pitch2	pitch3	pitch4	pitch5	pitch6	pitch7	cts1	cts2	cts3	cts4	cts5	cts6	cts7	degree1	degree2	degree3	degree4	degree5	degree6	degree7	scale
81	pl, 503,2c	W.Trumpets	G♭	A♭	B♭	C	D♭			0.0	200	369	550	668			I	II	III	IV	V			Natural
82	pl,505,1	W.Trumpets	F	G	A	B	C			0.0	189	371	556	690			I	II	III	IV	V			1/3 comma
83	CD26	W.Trumpets	G♭	A♭	A	C	D♭			0.0	208	348	563	681			I	II	III	IV	V			1/3 comma
84	pl,502,1c	W.Trumpets	F#	G#	A	C	C#			0.0	207	348	563	678			I	II	III	IV	V			1/3 comma
85	pl,502,2c	W.Trumpets	G♭	A♭	B♭	C	D			0.0	188	346	570	680			I	II	III	IV	V			1/3 comma
86	pl,504,2	W.Trumpets	G♭	A♭	B♭	C	D♭			0.0	199	391	577	704			I	II	III	IV	V			2/9 comma
87	CD10	**Skudučiai**	B	C#	D#	F	F#	G#	A#	0.0	247	393	558	694	949	1108	I	II	III	IV	V	VI	VII	Natural
88	pl,599,1	Skudučiai	F	A♭	A	B♭	C	D		0.0	276	415	542	710	906		I	III	III	IV	V	VI		Natural
89	pl,599,1b	Skudučiai	B	C#	D#	F#	A	A#		0.0	184	384	685	937	1081		I	II	III	V	VI	VII		1/4 comma
90	mg,565,7	Skudučiai	E♭	E	G	A				0.0	141	381	568				I	II	III	IV				1/3 comma
91	mg, 565, 11	Skudučiai	C	C#	E	F	G	A		0.0	157	415	489	732	940		I	II	III	IV	V	VI		Arabic
92	CD8	**Kanklės**	E	F#	G#	A	B	C#		0.0	215	431	513	714	926		I	II	III	IV	V	VI		Pythagorean
93	pl,405,6	Kanklės	B	C#	D#	F	F#	A		0.0	218	406	614	707	1006		I	II	III	IV	V	VI		Pythagorean
94	CD12	Kanklės	D♭	E♭	F	G♭	A♭	B		0.0	182	422	521	697	1010		I	II	III	IV	V	VII		2/9 comma
95	pl,596,1	Kanklės	B♭	C	D	E♭	F	G	A♭	0.0	167	366	496	703	864	939	I	II	III	IV	V	VI	VII	Arabic
96	FW04009_03.flac	**Smith-USA**	D	E	F					0.0	135	316					I	II	III					Arabic
97	FW04009_05.flac	Smith-USA	E	F#	G#	A	B	C#	D	0.0	184	426	510	707	884	1143	I	II	III	IV	V	VI	VII	Pythagorean
98	FW04009_06.flac	Smith-USA	G#	A#	B	C#	D#			0.0	179	315	484	661			I	II	III	IV	V			1/3 comma
99	FW04009_09.flac	Smith-USA	B	C#	D#	F#	G#			0.0	158	437	714	874			I	II	III	V	VI			Arabic
100	FW04009_10.flac	Smith-USA	A♭	B♭	B	D♭	E♭			0.0	185	294	501	668			I	II	III	IV	V			Werckmeister
101	FW04009_11.flac	Smith-USA	G	A	B	C	D			0.0	222	449	531	737			I	II	III	IV	V			Natural
102	FW04009_13.flac	Smith-USA	E♭	F	G♭	A♭	B♭			0.0	194	303	521	735			I	II	III	IV	V			1/3 comma
103	FW04009_14.flac	Smith-USA	G	A	B	C	D	E		0.0	211	383	486	680	837		I	II	III	IV	V	VI		Natural
104	FW04009_15.flac	Smith-USA	D#	F#	G#	A#	B	C#		0.0	357	544	711	820	1028		I	III	IV	V	VI	VII		Natural
105	FW04009_16.flac	Smith-USA	A	B	C	D	E	F#	G	0.0	210	355	525	712	890	1048	I	II	III	IV	V	VI	VII	Natural
106	FW04009_17.flac	Smith-USA	C	D	E♭	F	G	A	B♭	0.0	207	311	515	702	863	1031	I	II	III	IV	V	VI	VII	Arabic
107	FW04009_18.flac	Smith-USA	B	C#	D#	F#	G#	A		0.0	186	364	676	871	972		I	II	III	IV	V	VI		1/3 comma
108	FW04009_19.flac	Smith-USA	A	B	C#	D				0.0	200	394	467				I	II	III	IV				Natural
109	UDK 784.4(474.5)	Schellac-USA	F#	G#	A#	B	C#	D#	F	0.0	190	398	490	687	885	1101	I	II	III	IV	V	VI	VII	Werckmeister
110	UDK 784.3(474.5)	Schellac-USA	E	F#	G#	A	B	C#	D#	0.0	198	397	499	702	901	1098	I	II	III	IV	V	VI	VII	12-TET
111	UDK 784.4(474.5)	Schellac-USA	G	A	B♭	C	D	E♭	F	0.0	203	299	496	701	796	1003	I	II	III	IV	V	VI	VII	12-TET
112	UDK 784.3(474.5)	Schellac-USA	E	F#	G	G#	A	B	C#	0.0	201	310	401	512	703	904	I	II	III	IV	V	VI	VII	12-TET
113	UDK 821.172-3	Schellac-USA	F	G	A	B♭	C	D	E	0.0	199	397	518	710	898	1104	I	II	III	IV	V	VI	VII	12-TET
114	UDK 784.3(474.5)	Schellac-USA	F	G	A	B♭	C	D	E	0.0	209	400	500	710	905	1104	I	II	III	IV	V	VI	VII	12-TET
115	UDK 784.4(474.5)	Schellac-USA	E	F#	G#	A	B	C#	D#	0.0	205	405	516	710	895	1118	I	II	III	IV	V	VI	VII	Pythagorean
116	UDK 784.4(474.5)	Schellac-USA	F#	G#	A#	B	C#	D#	E	0.0	209	394	497	723	904	1006	I	II	III	IV	V	VI	VII	12-TET
117	UDK 784.4(474.5)	Schellac-USA	F#	G#	A#	B	C#	D#	F	0.0	198	391	497	710	898	1094	I	II	III	IV	V	VI	VII	Neidhardt
118	UDK 784.4(474.5)	Schellac-USA	D♭	E♭	F	G♭	A♭	B♭	C	0.0	195	384	494	695	884	1103	I	II	III	IV	V	VI	VII	Werckmeister

Fig. 13. (continued)

Comparing Songs to Temperaments

This was followed by separate studies into the vocal, instrumental, and Lithuanian-American song groups, and then by more detailed studies of *sutartinės*, monody, wooden trumpet, panpipes, *kanklės*, shellac collection, and Smithsonian song groups. All this material was compared first to all 13 temperaments, then to 12 temperaments

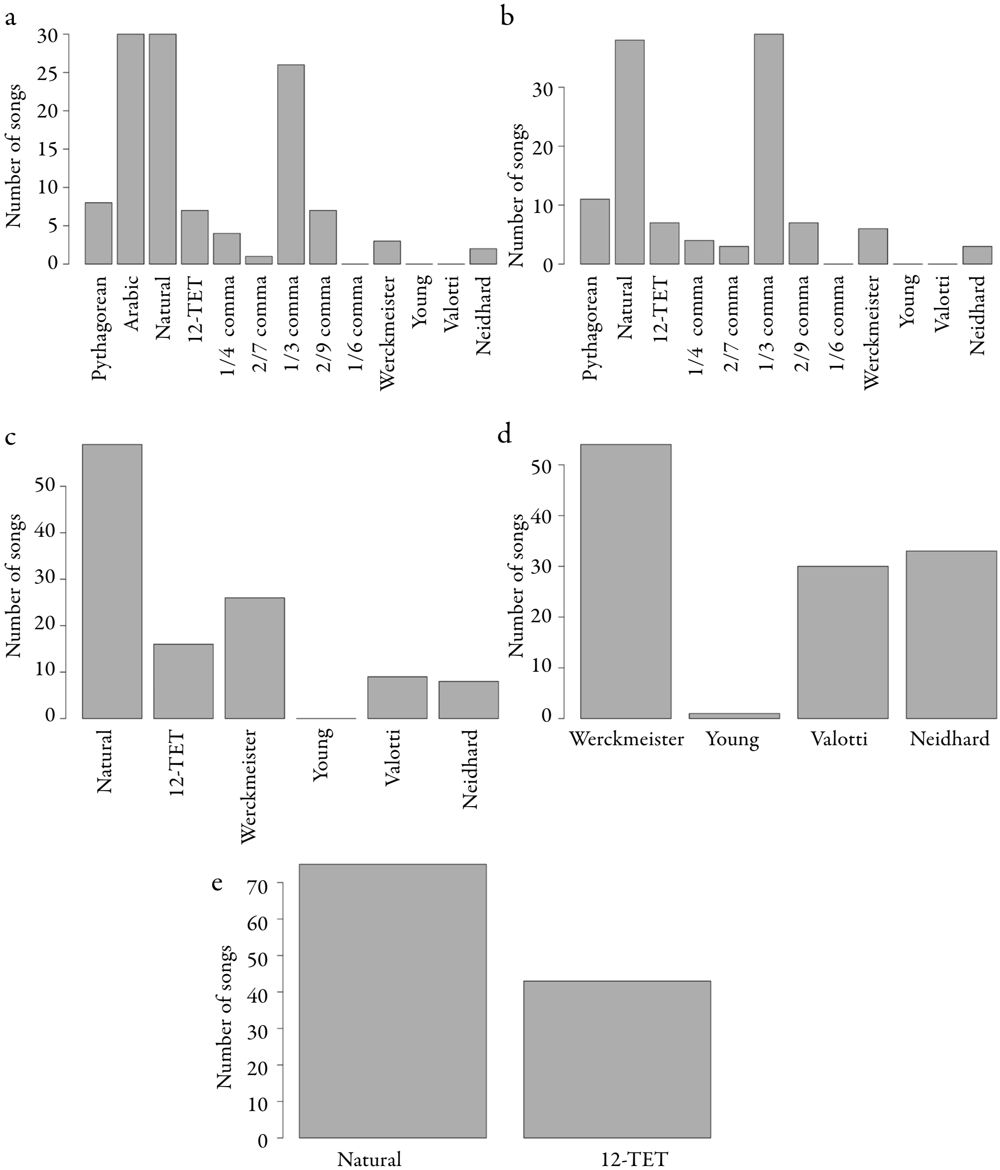


Fig. 14. In the diagram comparing 118 examples to five groups of temperaments, the bars indicate the number of songs from 0 to 70 and the tuning or temperament.

without Arabic tuning, to six temperaments (four well-tempered and natural and 12-TET), then to four well temperaments, and finally to natural tuning and 12-TET.

A comparison of the 118 examples with the 13 temperament systems shows that there are three tunings that correspond to the largest number of songs – natural and Arabic for 30 songs each, and 1/3 comma of the sixteenth century temperament (Francisco de Salinas) for 25 examples (Fig. 14a). However, if the Arabic tuning is excluded, which has a large number of natural intervals, then Fig. 14b shows that the number of songs corresponding to the natural and 1/3 comma tunings increases to well over 30. Excluding the comma

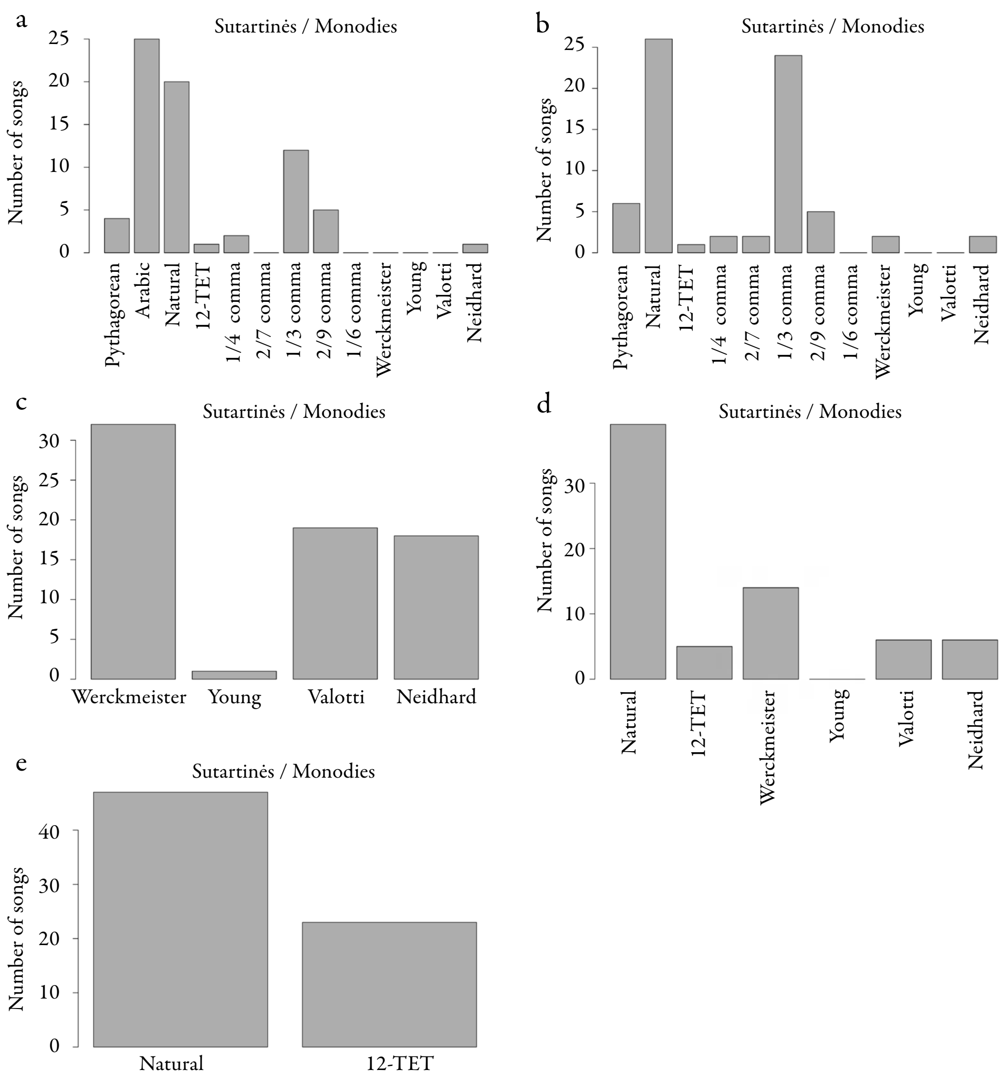


Fig. 15. In the diagram comparing vocal music examples to five groups of temperaments, the bars indicate the number of songs from 0 to 40 and the tuning or temperament

temperaments, Arabic and Pythagorean tunings, and comparing the eighteenth- and nineteenth-century well temperaments, plus the natural and 12-TET temperaments (Fig. 14c), natural tuning has the most examples (over 50), but the Werckmeister temperament appears in 25 examples. Comparing only the well-tempered tunings (Fig. 14d), the Werckmeister eighteenth-century temperament has the largest number of examples (over 50), followed by the Neidhardt and Valotti nineteenth-century tunings with 30 and over 30 songs, respectively. Finally, if all 118 songs are compared with natural tuning and 12-TET (Fig. 14e), natural tuning has over 70 examples and 12-TET has over 40 examples.

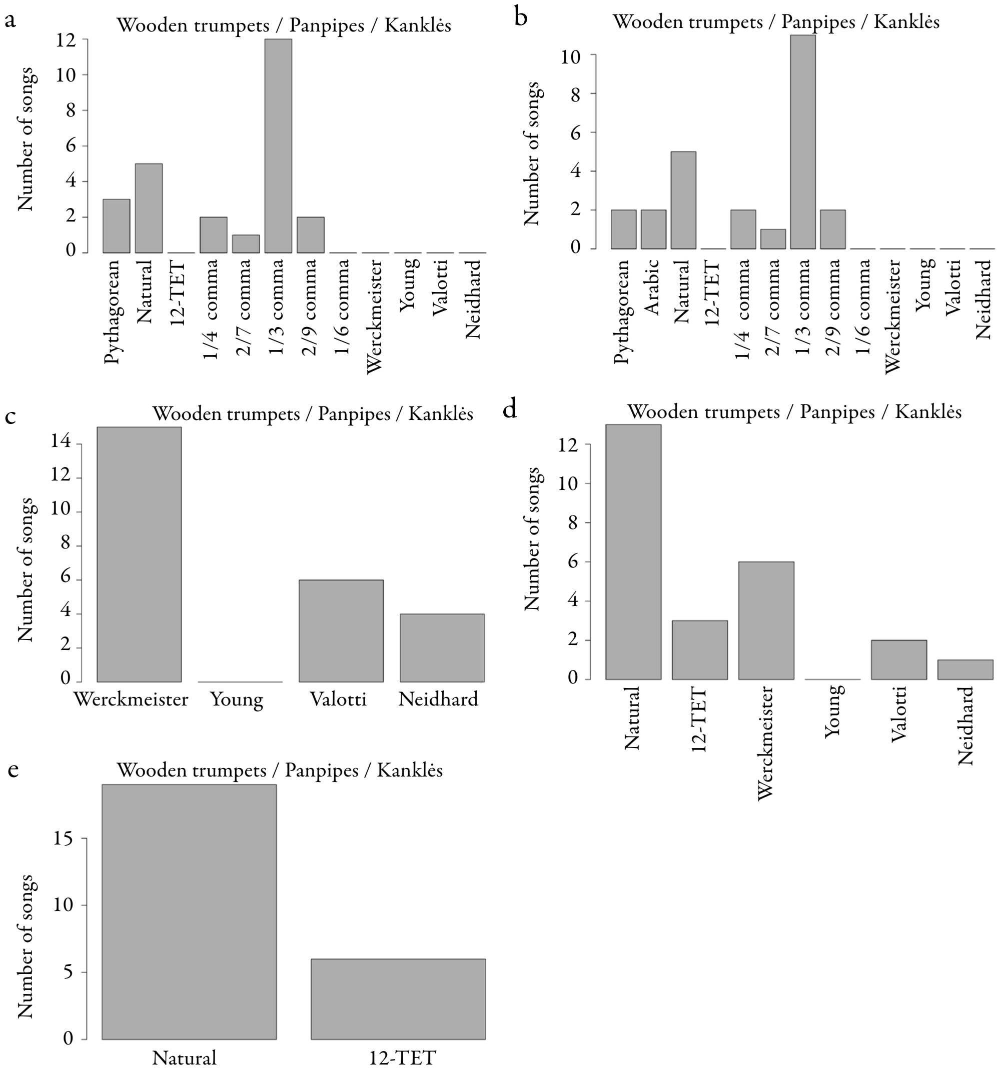


Fig. 16. In the diagram comparing instrumental music examples to five groups of temperaments, the bars indicate the number of songs from 0 to 15 and the tuning or temperament

If vocal music is examined as a group (Fig. 15), as in the previous comparison of 118 examples, three tunings are identified: natural, Arabic, and 1/3 comma (Fig. 15a, b, d, e), but in instrumental music the 1/3 comma temperament and natural tuning are dominant (Fig. 16a, b, d, e).

Figure 17 below shows that the separate song group of *sutartinės*, monodies, wooden trumpet, and panpipes have the same tuning tendencies as the previous

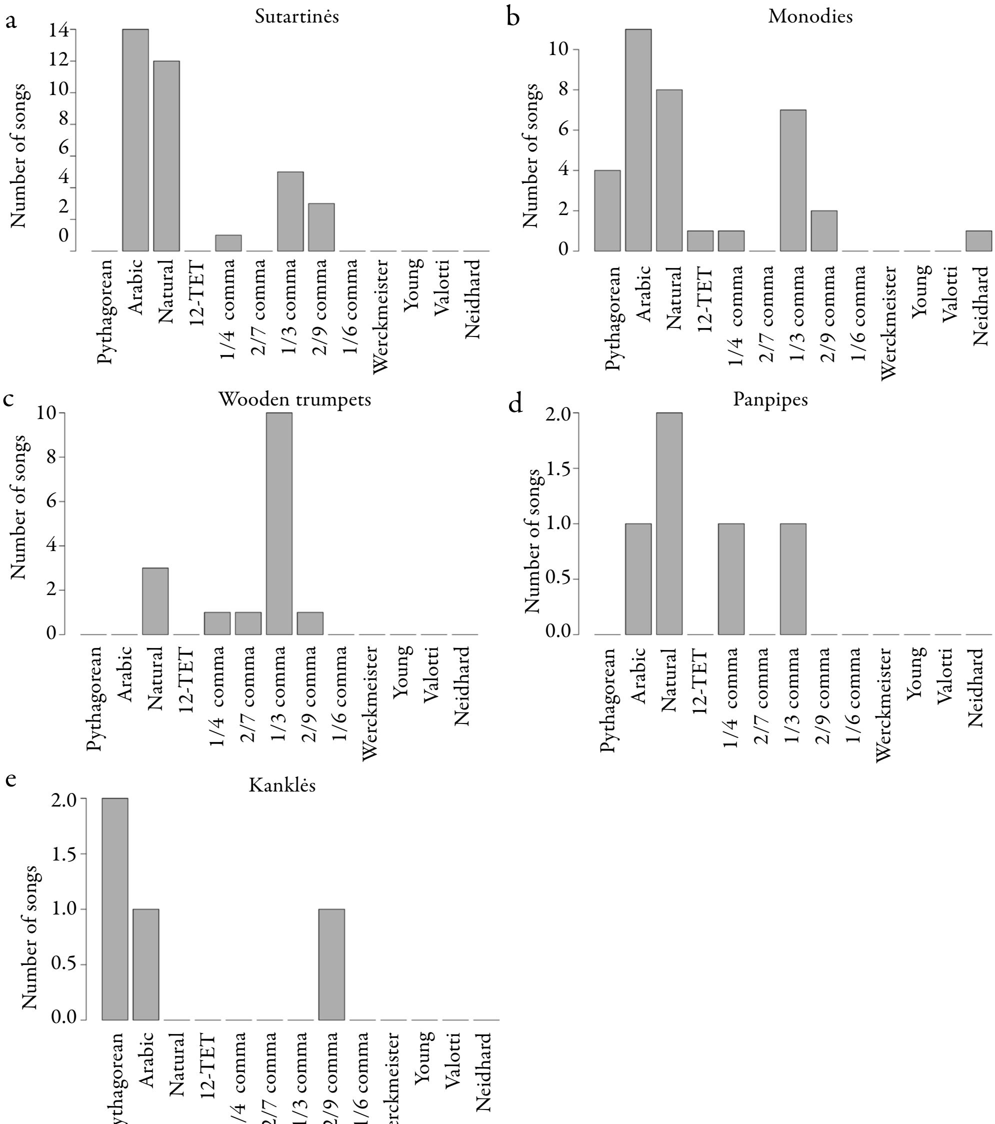


Fig. 17. In the diagram comparing separate song groups to 13 temperaments, the bars indicate the number of songs from 0 to 14 and the tuning or temperament

example groups: the natural, Arabic, and 1/3 comma tunings (Fig. 17a, b, c, d). It should be noted, however, that the tuning of the *kanklės* instrument (Fig. 17e) is closer to the Pythagorean tuning than to natural tuning.

Figure 18 summarises all the results of the research. The colours indicate the most common tunings and temperaments found in the scales: natural tuning is marked in yellow, 12-TET in red, 1/3 comma in green, the Arabic scale in violet, and the Pythagorean scale in blue.

Thus, the initial comparison of the 13 temperaments with the songs clearly showed the interval similarities of the songs with natural tuning and the Arabic scale, but after excluding the Arabic scale, its intervals fell into natural tuning and the 1/3 comma temperament because of the number of natural intervals. Then, after rejecting the Pythagorean tuning because of the small number of songs and the questionable influence of the Middle Ages on Lithuanian scales, the well temperaments for the eighteenth and nineteenth centuries, which should be closer to the early twentieth century recordings, were chosen along with natural tuning and 12-TET. However, natural tuning accounts for the largest number of samples.

Comparison of Lithuanian Immigrant Songs with Temperaments

Moving on to a ground of Lithuanian-American immigrant songs, these Lithuanian-American song samples were selected from the 1910–1929 Shellac collection and the 1955 Smithsonian Folkways collection and compared to the samples of singers recorded in Lithuania between 1935 and 1938. It is no coincidence that the Lithuanian-American interval distances are placed in a separate group, suggesting that since the 12-TET influence was already prevalent on the American continent at that time, it may have influenced the tuning of Lithuanian folk songs. The author hypothesised that the tunings of Lithuanian immigrant songs may have differed from those of performers in Lithuania.

From the first table (Figure 19a), if the Shellac/Smithsonian collections are examined together, the 12-TET temperament has a slight advantage, but if the recordings of the two collections are compared separately, as in the second and third table (Figure 19b, c), the Shellac collection is dominated by the 12-TET temperament while the Smithsonian collection is dominated by the natural, Arabic, and 1/3-comma temperaments. The single monody 'Vaikščiojo tėvulis' (The Father Was Walking) that was recorded by singers in Lithuania and the immigrants in the United States[24] will be used as a specific example.

24 The audio samples in this song were taken from the archives of the Smithsonian Institute Folkways Collection and the Institute of Lithuanian Literature and Folklore.

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Groups of songs / Number of songs	All songs (118)	Vocal (70)	Instrumental (25)	USA immi-grants (23)	Sutartinės (36)	Monodies (34)	Wooden trumpets (16)	Panpipes (5)	Kanklės (4)	Smithsonian Folkways (13)	Shellac (10)
13 Tunings (Pythagorean, arabic,natural, 12-tet, 5 comma, 4 well temper.)	Natural (30) Arabic (30) 1/3 - (26) Pythagor. (8) 12-tet (7) 2/9 - (7) 1/4 -(4) Werck. (3) Neidhardt (2) 2/7 - (1)	Arabic (25) Natural (20) 1/3 - (12) 2/9 - (5) Pythagor. (4) 1/4 - (2) 12-tet (1) Neidhardt (1)	1/3 - (11) Natural (5) Pythagor. (2) Arabic (2) 1/4 - (2) 2/9 - (2) 2/7 - (1)	12-tet (6) Natural (5) Arabic (3) 1/3 - (3) Werck. (3) Pythagor. (2) Neidhardt (1)	Arabic (14) Natural (12) 1/3 - (5) 2/9 - (4) 1/4 - (1)	Arabic (11) Natural (8) 1/3 - (7) Pythagor. (4) 2/9 - (2) 12-tet (1) 1/4 - (1) Neidhardt (1)	1/33 - (10) Natural (3) 1/4 - (1) 2/7 - (1) 2/9 - (1)	Natural (2) Arabic (1) 1/4 - (1) 1/3 - (1)	Pythagor. (2) Arabic (1) 2/9 - (1)	Natural (5) Arabic (3) 1/3 - (3) Pythagor. (1) Werck.(1)	12-tet (6) Werck.(2) Pythagor. (1) Neidhardt (1)
12 Tunings (except arabic scale)	1/3 - (40) Natural (38) Pythagor. (11) 12-tet (8) 2/9 - (8) Werck. (6) 1/4 - (3) 2/7 - (2) Neidhardt (2)	Natural (26) 1/3 - (24) Pythagor. (6) 2/9 - (5) 1/4 -(2) 2/7 - (2) Werck. (2) Neidhardt (2) 12-tet (1)	1/3 - (12) Natural (5) Pythagor. (3) 1/4 - (2) 2/9 - (2) 2/7 - (1)	Natural (7) 12-tet (6) Werck. (4) 1/3 - (3) Pythagor. (2) Neidhardt (1)	Natural (14) 1/3 - (14) 2/9 - (3) Pythagor. (1) 1/4 - (1) 2/7 - (1) Neidhardt (1)	Natural (12) 1/3 - (10) Pythagor. (5) 2/9 - (2) Werck. (2) 12-tet (1) 1/4 - (1) 2/7 - (1) Neidhardt (1)	1/3 - (10) Natural (3) 1/4 - (1) 2/7 - (1) 2/9 - (1)	Natural (2) Pythagor. (1) 1/4 - (1) 1/3 - (1)	Pythagor.(2) 1/3 - (1) 2/9 - (1)	Natural (7) 1/3 - (3) Werck.(2) Pythagor. (1)	12-tet (6) Werck.(2) Pythagor. (1) Neidhardt (1)
6 Tunings (4 well temper., natural,12-tet)	Natural (59) Werck. (25) 12-tet (15) Valotti (10) Neidhardt (9)	Natural (40) Werck. (15) Valotti (5) Neidhardt (5) 12-tet (4)	Natural (13) Werck. (6) 12-tet (3) Valotti (2) Neidhardt (1)	+12-tet (8) Natural (7) Werck. (6) Valotti (1) Neidhardt (1)	Natural (20) Werck.. (6) Valotti (4) Neidhardt (4) 12-tet (2)	Natural (20) Werck. (8) 12-tet (3) Valotti (2) Neidhardt (2)	Natural (9) Werck. (5) Valotti (1) Neidhardt (1)	Natural (4) 12-tet (1)	12-tet (2) Werck. (1) Valotti (1)	Natural (7) Werck. (4) 12-tet (1) Valotti (1)	12-tet (7) Werck. (2) Neidhardt (1)
4 Tunings (well temper.)	Werck. (53) Valotti (30) Neidhardt (34) Young (1)	Werck. (32) Valotti (19) Neidhardt (18) Young (1)	Werck. (15) Valotti (6) Neidhardt (4)	Neidhardt (11) Werck. (7) Valotti (5)	Werck. (16) Valotti (10) Neidhardt (10)	Werck. (17) Valotti (8) Neidhardt (7) Young (2)	Werck. (13) Valotti (2) Neidhardt (1)	Valotti (2) Neidhardt (2) Werck. (1)	Valotti (2) Werck. (1) Neidhardt (1)	Werck. (5) Valotti (4) Neidhardt (4)	Neidhardt (7) Werck. (2) Valotti (1)
2 Tunings (natural / 12-tet)	Natural (75) 12-tet (43)	Natural (47) 12-tet (23)	Natural (18) 12-tet (7)	12-tet (14) Natural (9)	Natural (24) 12-tet (12)	Natural (23) 12-tet (11)	Natural (14) 12-tet (2)	Natural (4) 12-tet (1)	12-tet (3) Natural (1)	Natural (9) 12-tet (4)	12-tet (10)

Fig. 18. A column shows the group and number of songs compared to the five temperament groups. The colours indicate the most common tunings and temperaments: yellow – natural tuning; red – 12-TET; green – 1/3-comma meantone; violet – Arabic scale; blue – Pythagorean tuning

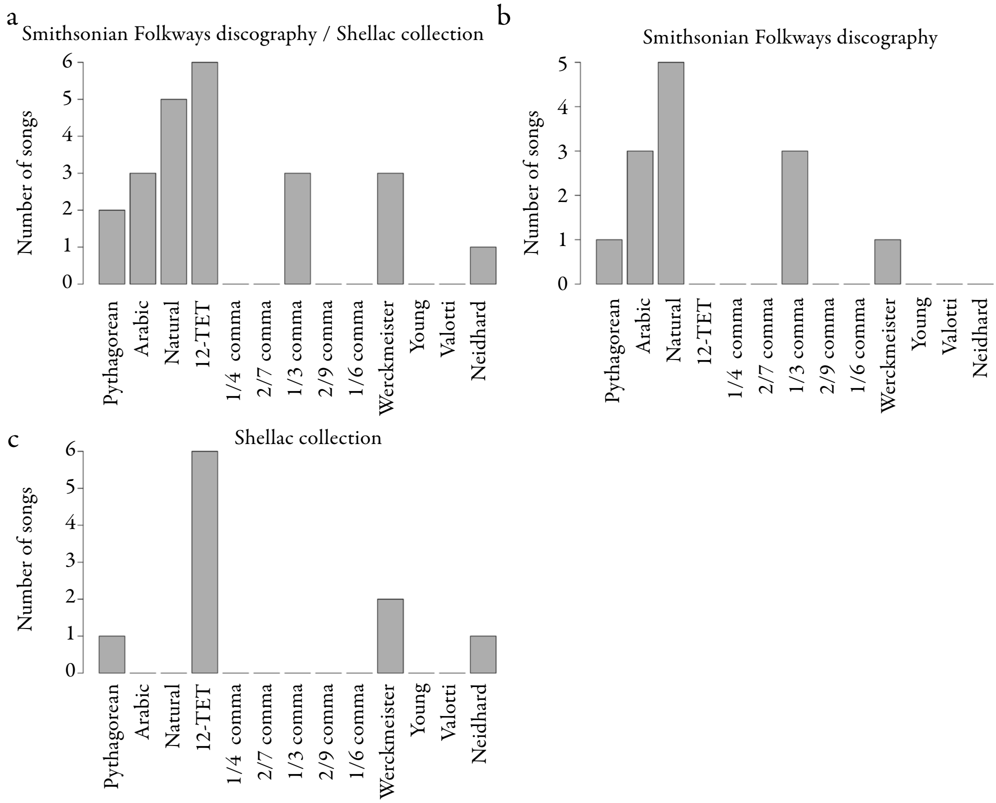

Fig. 19. The diagram compares three groups of Lithuanian immigrant songs with 13 temperaments. The bars indicate the number of songs from 0 to 6 and the tuning or temperament

Comparing the Single Monody in Lithuania and the USA

In the example below (Fig. 20), the analyses of the interval distances in yellow of the monody recorded in the United States shows that the tuning gradually narrows to equal temperament, but still maintains almost the exact interval of the diminished fourth (471 cts, or 21 harmonic), with the second degree equal tempered at 200 cts and the third degree approaching 400 cts.

Vaikščiojo Tėvulis / The Father Was Walking

Smithsonian Folkways FW04009_19.flac

Degrees	I	II	III	IV
Distances	0.0	200	394	467
Natural tuning	0.0	204	386	471
Deviation		–4	+8	–4

Performed by E. Pigagienė, b. 1884, town Perloja, immigrated to the USA in 1905, and L. Andriušienė, b. 1892, Vartalaukis, Nedzingė parish, immigrated to the USA in 1909, recorded in 1949

LTRF mg, 42, 2

Degrees	I	II	III	IV
Distances	0.0	187	367	471
Natural tuning	0.0	204	386	471
Deviation		–17	–19	0

Performed by Marė Kašėtienė (Tamulevičiūtė), b. 1880, Mergežeris village, Varėna parish, Varėna county, recorded in 1958

LTRF pl, 485, 4

Degrees	I	II	III	IV
Distances	0.0	191	350	471
Arabic tuning	0.0	204	355	498
Deviation		–13	–5	–27

Performed by Morta Jovaišienė (Juknevičiūtė), b. 1869, Subartonys, Merkinė parish, Alytus county, Ieva Milienė (Jovaišaitė), b. 1906, Subartonys, Merkinė parish, Alytus county, recorded in 1936

Fig. 20. Three analyses of one Lithuanian song recorded by different singers at different times in Lithuania and the USA compared to the natural and Arabic tunings indicate the interval distances of the scale and deviation in cents. One song is FW04009_19.flac (Smithsonian Folkways Discography Collection, USA), and the other two are LTRF mg, 42, 2; LTRF pl, 485, 4 (Archive of the Institute of Lithuanian Literature and Folklore)

Looking at the intervals of the three recordings of a single song and the dates of the recordings in Lithuania and the USA, a gradual approach to the 12-TET is observed (Fig. 21). For example, the interval of the major second in Lithuania of 191 ct (recorded in 1936) and 187 ct (recorded in 1958) is almost the same, but in the recording made in the USA it is 200 ct (recorded in 1949); the interval of the major third in Lithuania of 350 ct (recorded in 1936) and 367 ct (recorded in 1958) only slightly changes, remaining far enough from the major third of 400 ct of equal temperament, but in the USA the major third 394 ct is already approaching 12-TET, i.e., the migration of the interval of the third from 350 cents in Lithuania to 394 cents in America can be clearly observed.

		Lithuania		USA
Scale degrees	II	187 ⇒	191 ⇒	200
	III	350 ⇒	367 ⇒	394
	IV	471⇒	471 ⇒	467
Year recorded		1936	1958	1949

Fig. 21. Comparison of the monody recorded in Lithuania and the USA. The interval distances are displayed in three columns for each audio track of the same song marked by the year of recording. The scale degrees indicate the variability in the size of the interval measured in cents.

Conclusions

The method of comparative analysis revealed and identified similarities of microtonal structures by comparing Lithuanian traditional music scales with European and Asian unequal temperament systems. A general formula was used to carry out the analysis and analogy methods of unequal interval structures that corresponded to close identical, dominant temperament systems and tunings. This study shows that no single specific temperament or tuning was found in all the examples of vocal and instrumental music; instead, four tunings were detected in many songs: natural tuning, a partial Arabic scale with a lowered second or third degree, the 1/3 comma meantone temperament, and the Pythagorean tuning in the music of the kanklės instrument. If, however, the graphs of recordings made in Lithuania are examined more closely, a clear predominance of natural intervals or historical temperaments emerges, but the audio recordings made in the USA, for example, in the Shellac collection, are dominated by the 12-TET, while in the Smithsonian Folkways collection some intervals still retain the old Lithuanian intonations, but a gradual transition towards an equal temperament system of the songs recorded both in Lithuania and the USA is observed. However, historical audio recordings indicate that, prior to this, Lithuanian music was dominated by natural, unequal scales, which can be regarded not only as part of the musical heritage but also as a valuable source for research aimed at understanding regional intonational traditions and their connections to global systems of temperaments. The conclusions of this study suggest that traditional Lithuanian music, especially old folk songs and instrumental music, has retained a variety of scales that reflect the sound of natural intervals.

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Vytautas Germanavičius

Lietuvių tradicinių dermių palyginimas su istorinėmis temperacijų sistemomis

Santrauka

Šio meninio tyrimo naujumą ir aktualumą sudaro tradicinių lietuviškų netolygaus derinimo intervalų palyginimas su Europos ir Artimųjų Rytų temperacijų sistemomis, kuriuo siekiama nustatyti intervalų atstumų panašumo ir skirtumo lygį. Naujumą lemia ir plati tyrimo apimtis: nagrinėjami XX a. pirmosios pusės lietuvių liaudies muzikos įrašai, saugomi Lietuvoje bei JAV. Galima teigti, kad 12-os lygių garsų temperacijos sistema (12-TET) turėjo įtakos lietuvių muzikos tradiciniams derinimams, tačiau ankstesni moksliniai tyrimai, skirti lietuvių tradicinei vokalinei ir instrumentinei muzikai, atskleidė, kad 12-TET sistema nėra plačiai paplitusi. Vis dėlto mikrointervalai lietuvių muzikoje išlaikė savo unikalumą ir savitumą, palyginti su kaimyninėmis šalimis (Latvija, Estija, Lenkija ir Suomija), kuriose natūralių intervalų ar derinimų neaptikta. Projekto tikslas – palyginti istorines netolygias derinimo sistemas su lietuvių liaudies muzikos dermėmis pasitelkiant kompiuterines technologijas. Tyrimo metu naudoti šie metodai: a) lyginamasis metodas – Europos ir Azijos netolygios temperacijos sistemų analizė, paremta natūraliojo garsaeilio sekos derinimu, ir lietuvių tradicinės muzikos dermės; b) programinė R statistinė analizė, naudojama failų sistemos tekstinei informacijai apdoroti. Galima daryti išvadą, kad lietuvių liaudies dainose aptikta daug natūralių intervalų, atsižvelgiant į tai, kad ankstesnių šimtmečių temperacijos pasižymėjo natūraliai suderintų intervalų gausa.

REIKŠMINIAI ŽODŽIAI: lietuvių liaudies dermės, intervalų atstumai, netolygios temperacijos sistemos, mikrotonai, natūralūs intervalai, 12-TET