Imitations of Bells: Correspondence between Bell Acoustics and Onomatopoeic Texts

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Background in ethnomusicology and linguistics. Church bells have played and still play an important role in Eastern European communities (cf. Sachs, 1930, p. 54; Vîlyûs, 2000; Agapkina, 1999). In Lithuania, sets of three to five bells are used; the techniques of ringing and the sizes of the bells are different for different announcements. These formulaic techniques are reflected in the vocal imitations of bells (a layer of folklore). So far these imitations of bells have not been studied at all. From the point of view of quantitative linguistics, these imitations could be analyzed in terms of frequencies of certain sounds and their combinations. Quite a few studies have dealt with the frequencies in standard Lithuanian (see below).

Background in acoustics. The basics of bell acoustics are well known (cf. Fletcher & Rossing, 1998, p. 675-707). For the present study, knowledge of the dominant bands in the bell spectrum and the decay times for different partials (long for low partials and short for high partials; cf. Perrin et al. 1983) seem to be the most applicable. Relevant features of voice acoustics are also well studied; namely, the dependence of vowel phonetics on two first formants as well as the features of nasals and plosives (cf. Kent & Read, 2002). Phonetic analogies of instrumental timbres have been discussed (e.g., for guitar timbre: Traube & Depalle, 2004).

Aims. We aim to reveal the regularities in phonetics of bell imitations (Lithuanian traditional bell imitations and nonsense syllables) and their origins in bell acoustics.

Main contribution. Frequencies of occurrences of certain speech sounds and their combinations in standard Lithuanian, traditional Lithuanian vocal imitations of bells, and in the nonsense syllables evoked by bell strokes (imitation experiment) were analyzed. The statistical analysis of bell imitations reveals some correspondence between bell size and the phonetic quality of vowels. The largest bell frequently evokes a perception of back vowels, while the smallest one results predominantly in front vowels. Some syllables are especially frequent in the imitations (based on different vowel diphthongs or starting from voiced plosives and ending with nasals, such as [din], [dan]). On the other hand, the acoustical analysis of the bell spectra also reveals similar correspondences between bell size and the acoustic-phonetic quality of vowels (in terms of formants). The perception of consonants (first of all, the initial [d] and the final nasals), can be attributed to the overall dynamics and the dynamic changes in the spectra (prominence of low partials at the end of sound due to their slow decay, etc.). Generally, the traditional imitations and the statistics of their phonetics present an intermediate case between standard Lithuanian and the imitations of bells using nonsense syllables.

Implications. Phonetics of vocal imitations of bells can be explained by features of bell acoustics collated to acoustical phonetics. The present study could be further extended to other cases of onomatopoeia, also to a cross-cultural domain. It provides new data for research regarding analogies between instrumental timbres and phonetics. A comprehensive account of the phenomena of folk onomatopoeia requires expertise in both the humanities (ethnomusicology, music analysis, etc.) and the sciences (acoustics, statistics).

Keywords: bells, onomatopoeia, acoustical phonetics, Lithuanian traditional culture

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Introduction

Vocal imitations of bells are widely found in a variety of musical cultures. It is enough to recall the well-known Frère Jacques: [...] Sonnez les matines! / Din, dan, don. Here the lyric is composed of the notional text not imitating the bell strokes (Frère Jacques,..) and purely onomatopoeic (nonsense) syllables (Din, dan, don). Vocal imitations of church bells, along with other vocal imitations, are also part of Lithuanian folklore. Some examples are also composed of notional text and nonsense syllables, for instance: O kaip linksma to adyna, to adyna, / Kad jau varpas gult vadina, gult vadina, / Bim, bam, baim, bam, baim, bam (“O how jolly is the hour / When the bell beckons us to go to sleep / Bim, bam,...”). Some syllables of notional text also frequently imitate, more or less successfully, the bell strokes themselves, for instance: Dievs danguij, Dievs danguij (“God in heaven, God in heaven!”).

Naturally, one can presume that the vocal imitations of bells are somehow connected to the acoustics of bells. These connections are discussed in the present paper. Frequencies of occurrences of various speech sounds in Lithuanian traditional vocal bell imitations are compared with the frequencies in standard Lithuanian and collated with the results of acoustical analyses of bell strokes. In addition, an imitation experiment was carried out in which the respondents were asked to write down the nonsense syllables matching the bell strokes.

A collection of traditional onomatopoeic texts was prepared and the preliminary partition into classes according to bell sizes was done by Renata Balsienè. The remaining part of the study was done by Rytis Ambrazevičius.

Some notes on bells in Lithuanian traditional culture

Church bells came to Lithuania with Christianity, therefore it is a relatively new phenomenon in the Lithuanian context.¹ The first bell in the Great Duchy of Lithuania was cast in 1377 (Martiniatiené, 2007, p. 5). The bells were made mostly in armament foundries. Nevertheless, some predecessors of bells were known considerably earlier. Jingles for decoration of apparel are found in shrouds dating back to the first centuries A.D. (Jasinevičiūtė-Ivanauskienė, 2002, p. 12). Primitive, mostly wooden idiophones Tabalas, Skrabalai and others had similar functions as church bells.

The typical sets of bells in belfries of Lithuanian churches contain from three to five bells (large, medium and some small).² There are several ringing patterns closely related to certain functions of ringing: 1) the clapper is swayed to strike both sides of the bowl – used for summons to usual services, announcement of death, and timekeeping; 2) the clapper strikes one side of the bowl – for summons to seasonal services and extraordinary gatherings (different bells can be used); and 3) the clapper of the small bell strikes one side of the bowl strong and fast – for announcement of fire and alert.

The patterns of ringing bells are reflected in vocal imitations, which can be considered small forms in folklore, together with other vocal imitations (of birds,
Imitations of bells

The bell imitations fall into the intermediate domain of speechlike/musical vocalizations: although some examples are characteristic of musical intonation, intermediate or speechlike cases are prevalent. Thus, the aspects of phonetics and rhythm appear to be the most important. The structure of the imitations is mostly astrophic, containing up to three lines and, seldom, strophic. The subjects of heaven, death, and toponymes prevail in the notional texts.

The imitations had no special function and were used for merriment or to play with children (e.g., to develop pronunciation and a sense of rhythm). However, this information is from quite recent records. Quite a few occurrences of references to bells in Lithuanian folklore (songs, tales, riddles, proverbs; also beliefs) suggest their importance in the culture. Bells act as mediators between this world and beyond, and as guard for the deceased, accompanying him/her on the final journey. Obviously, the main reason of the specific role of a bell is its peculiar sound. This fact is encoded even in the name of the bell and its etymology. For instance, varpas ‘bell’ is linked to virpėti ‘to vibrate, quiver’, varpyti ‘to spear, bore (incl. e.g., air by sound)’ and so on. According to Toporov (1975, p. 65), when comparing with examples in other Indo-European languages, the common root wārp (‘envelopment, protection, proximity’) can be derived.

Incidentally, some parallels between bell and voice acoustics were previously noted for vocal Schwebungsdiaphonie (traditional ‘beat diaphony’ found in the Balkans, Lithuania, and elsewhere; Brandl, 1989; Ambrazevičius, 2005). These mainly include the correspondence between the dominant spectral bands and the features of inharmonic spectra. Nevertheless, the correspondence between bell acoustics and the acoustics of vocal bell imitations lacks comprehensive studies.

Methods

Analysis of traditional imitations of bells

Records of the traditional Lithuanian vocal imitations of bells are not plentiful. With a few exceptions, they are in written (phonemic textual) form only. Thus, only the information extracted from this form was considered in the present paper. The main source of the imitations is the collection by Kalvaitis (1905) from Lithuania Minor.

For the present study, ninety-eight examples of Lithuanian traditional bell onomatopoeia have been collected from different sources; see some examples presented in Table 1. The collection by Kalvaitis comprised the largest number of items (55). The remaining items were found in several archives of Lithuanian traditional music and publications. Only a few of the examples contained supplementary notes on the sizes of the bells imitated. Therefore, a preliminary division of the examples into three classes associated with large, medium, and small bells was made. There were several criteria for assigning certain onomatopoeic texts to a certain class (large, medium, small). First, obviously, the remarks on the sizes were taken into account. Then, the identical examples, in a sense of feet-formulae of
Table 1. Examples of Lithuanian traditional bell onomatopoeia (the originals with places and sources noted, approximate phonetic transcriptions, and English translations).

<table>
<thead>
<tr>
<th>Lithuanian</th>
<th>Approximate phonetic transcription</th>
<th>English translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>O kaip linksma</td>
<td>oː keɪʔtʃ porterkšmą</td>
<td>O how jolly</td>
</tr>
<tr>
<td>to adyna,</td>
<td>tɔː tʃdʒiːnɔ</td>
<td>is the hour, is the hour,</td>
</tr>
<tr>
<td>Kad ja varpas</td>
<td>kad ʃuː ʃaɾpas</td>
<td>When the bell, beckons us to go to sleep, beckons us to go to sleep,</td>
</tr>
<tr>
<td>gult vadina,</td>
<td>gult vaɾdʒiːna</td>
<td>Bim, baim, baim, baim,</td>
</tr>
<tr>
<td>Bim, baim, baim,</td>
<td>bim baim baim</td>
<td>Bim, baim, baim, baim,</td>
</tr>
<tr>
<td>Rokiškis. LTR 1860(175)</td>
<td>ʃaɾm ʃaɾm ʃaɾm.</td>
<td>Bim, baim, baim, baim,</td>
</tr>
<tr>
<td>Dievs dangųjį</td>
<td>dʒiːɾʃa dʒaŋuːri</td>
<td>God in heaven, God in heaven!</td>
</tr>
<tr>
<td>Duesia dangųjį,</td>
<td>dʒeːʃia dʒaŋuːri</td>
<td>Soul in heaven, Body underground!</td>
</tr>
<tr>
<td>kuns po žemes!</td>
<td>kuns po ʒaːmesi</td>
<td>Soul in heaven, Body underground!</td>
</tr>
<tr>
<td>Šilgišiai. (Kalvaitis, 1910, p. 526)</td>
<td>ʃaːk vok gwaːdok</td>
<td>Thank, chant!</td>
</tr>
<tr>
<td>Dekauok, giedok!</td>
<td>ʤekauok ʤaːdok</td>
<td>Thank, chant!</td>
</tr>
<tr>
<td>Brolau, skendau!</td>
<td>bɾəɬəˈur</td>
<td>skændəˈur.</td>
</tr>
<tr>
<td>Bim, baim...</td>
<td>bim baim</td>
<td>Bim, baim...</td>
</tr>
<tr>
<td>Duesia dangųjį,</td>
<td>dʒeːʃia dʒaŋuːri</td>
<td>Soul in heaven, Body underground!</td>
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<td>ʤekauok ʤaːdok</td>
<td>Thank, chant!</td>
</tr>
<tr>
<td>Lisk duobėn,</td>
<td>liːsk duːˈbeːn</td>
<td>Climb into the grave, Climb into the grave!</td>
</tr>
<tr>
<td>Lisk duobėn!</td>
<td>liːsk duːˈbeːn</td>
<td>Climb into the grave, Climb into the grave!</td>
</tr>
<tr>
<td>Aš nedaviu, aš nedaviu!</td>
<td>aʃ ʃədəːviː əʃ ʃədəːviː</td>
<td>I didn’t give, I didn’t give! (If somebody did not contribute to the collection for bell purchase, the bell expressed its condemnation in this way)</td>
</tr>
<tr>
<td>Žemaicių Kalvarija.</td>
<td>Žemaicių Kalvarija.</td>
<td>(When the deceased is brought to church)</td>
</tr>
<tr>
<td>(Šverebas, 2005)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ak šen, ak šen, šen...</td>
<td>ak ʃən ak ʃən ak ʃən</td>
<td>Come here, come here here...</td>
</tr>
<tr>
<td>Žemaicių Kalvarija.</td>
<td>Žemaicių Kalvarija.</td>
<td>(When the deceased is brought to church)</td>
</tr>
<tr>
<td>(Šverebas, 2005)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
speech rhythm, were assigned to the same classes. The analysis of the remarks also led to the conclusion that smaller bells were associated with longer lines and feet containing more unaccented syllables. The higher rate of onomatopoeic speech (when articulating the text in a natural way), the smaller the bell that was supposed to be imitated: typically, smaller bells are struck with higher rates (see, e.g., our examples, Vilyš, 2000). To generalize, the speech rhythm in assigning certain onomatopoeic text to a certain class was considered to be of major importance. Additionally, some other “markers” were considered. For instance, diminutives in the imitating texts suggested associations with small bells.\(^5\)

For the subsequent analysis, the two most contrasting classes (large / small) were considered. The percentage of certain speech sounds and their combinations (see below) was calculated. The procedure was comprised of the following steps: 1. The number of the syllables in each onomatopoeic example analyzed containing a certain sound (-combination) was divided by the total number of syllables in the example. 2. The resulting percentages were averaged across all examples of interest. 3. Tense and lax versions of the vowels (e.g., [i] and [iː]) were pooled.

**Experiment: nonsense syllables evoked by bell strokes**

For the imitation experiment, four examples of recordings of bell sounds were prepared. The first example consisted of two strokes of a large bell (pitch of the strike tone ~D#4, time interval between two succeeding strokes ~1.2 s). The second example consisted of four strokes of a small bell (pitch of the strike tone ~C#5, time interval between two succeeding strokes ~1.0 s). For the third and the fourth examples, recording of two clashing bells with slightly different medium pitches of the strike tones (~F#4 and ~G#4) was applied. The two examples differed in the pitch patterns: short higher strokes followed by longer and lower strokes (Example 3; Figure 1), or vice versa (Example 4; similar rhythm patterns to those in Figure 1).

The respondent group consisted of 20 persons. The respondents were mostly 20-25 years old with similar musical backgrounds (mostly students of the Lithuanian Academy of Music and Theatre).\(^6\) The participants of the experiment were asked to write down the (nonsense) syllables which they felt best matched the bell strokes. Attention was paid to (as careful as possible) specification of the initial consonants (if they are heard at all) and succeeding vowels, VV or VC diphthongs and other sound combinations if they matched the bell strokes better. The participants could listen to successive examples as many times as needed; they could also revise their records returning back to the examples already processed. They were also told to write down several variants of the syllables if they thought numerous variants matched the bell strokes.
As in the analysis of the Lithuanian traditional onomatopoeia, tense and lax versions of the vowels were pooled. Thus six classes corresponding to the six Lithuanian vowel classes were composed: \( u, o, a, e ([æ]), ė, \) and \( i \). Then the statistical analysis was carried out, as was done in the case of Lithuanian traditional onomatopoeia.

Acoustical analysis

Software Praat\(^7\) was applied. The recordings of bell strokes used in the imitation experiment were analyzed. The main parameters and processes discussed were SPL dynamics, spectra of the sounds and the spectral dynamics (temporal change). The parameters of spectrum of interest were the formant frequencies (F1 and F2) and the spectral centre of gravity.\(^8\)

Frequencies of occurrence of phonemes and their combinations in Lithuanian prose

The novel “Baltaragio malūnas” (“Baltaragis’ Mill”, 1945) by Lithuanian writer Kazys Boruta was chosen as an example of Lithuanian prose. The text was downloaded from the Internet\(^9\). Personal names and toponymes occurring frequently in the text (such as Baltaragis, Pincukas, Udrave, etc.) were removed from the text to be analyzed to avoid possible pervasive influence on the statistics. Thus a total of 268,199 characters, 106,111 syllables, and 48,492 words were used for the analysis.

The percentage of some speech sounds and their combinations (see; “Results” below) was calculated. The number of the syllables containing certain sounds (-combination) was divided by the total number of syllables in the prepared text of the novel.

It should be noted that while the studies dealing with the frequencies of certain sounds and their combinations in standard Lithuanian are numerous (for instance, Karosienė & Girdenis, 1993; Girdenis & Karosienė, 1995; Kazlauskienė, 2007; other papers by these authors and others), here the statistical procedures were executed anew. The main reasons were the following: (1) some relevant sound combinations were previously not considered, (2) the algorithms for analysis of the frequencies are quite
diverse depending on the aim of the study (and, moreover, sometimes not accurately specified).

**Results**

**First vowels in syllables**

**Statistical analysis.** There are several vowel diphthongs (VV) constituting the nuclei of syllables, such as *ai, au,* or *ui,* in standard Lithuanian. The statistics of the single vowels pooled with the first components of the vowel diphthongs is discussed in this chapter. Figure 2 shows some cumulative results.

![Figure 2](image)

**Figure 2.** Syllables with back and front vowels (or first components of vowel diphthongs). The cases of small and large bells are depicted. See the text for abbreviations.

The percentages of back and front vowels are displayed for standard Lithuanian (L), Lithuanian traditional onomatopoeia of bells (O), and the imitations of bells in the imitation experiment. 1-2 stands for the 1st and 2nd examples (small and large bells in ~C#5 and ~D#4), and 3-4 stands for the 3rd and 4th examples (medium bells; smaller in ~G#4 and larger in ~F#4). It may be concluded that the large bells are associated more with back vowels while the small bells predominantly evoke perception of front vowels. This contrast is most pronounced in the experiment with the most diverse bell sizes (i.e., the most different strike tones; Examples 1 and 2). When the bells differ less, the phonetic quality of the vowels assigned to the bells differs less as well (Examples 3 and 4). The difference is even smaller in the case of traditional onomatopoeia. This can most probably be explained by two reasons. First, the phonetic contrast is diminished because the notional text is used in the onomatopoeia alongside the nonsense syllables. Second, there could be some problems with the preliminary and rough assigning of onomatopoeic texts to the classes of bell sizes.
Figure 3. Syllables with different vowels (or first components of vowel diphthongs); Examples 1 (large bell; ~D#4) and 2 (small bell; ~C#5) of the imitation experiment.

In addition, see Figure 3. It appears that mostly as (or diphthongs a...) are used for the large (~D#4) bells while is predominate for the small (~C#5) bells.

Acoustical analysis. Examples 1 and 2 (low- and high-pitched bell strokes) in the imitation experiment were considered. Generally, the envelope of a bell spectrum is quite different from that of the human voice. Nevertheless, Praat was “forced” to evaluate the frequencies of the first two formants from the bell spectra. Of course, it does not necessarily mean that such formants exist in reality, but at least it simulates the attempt to recognize a vowel in the sound of a bell.

Such “formant frequencies” were evaluated for two strokes of the large bell (Example 1), for two time intervals in both strokes: the beginning of the stroke (from the moment of the maximum SPL in the attack, plus 300 ms), and the audible end of the stroke (just before the succeeding stroke minus 300 ms). The values for the two strokes were averaged; Figure 4 shows the results.

The same was performed for the small bell (Figure 5). Also, the change of the spectral centre of gravity was evaluated for both bells (Figure 6).

On the other hand, the data of F1-F2-measurements in speech can be discussed (Figure 7). Collation of the results for bells (Figures 4 and 5), speech (Figure 7), and the statistics of the vowels (single vowels or the first components in VV diphthongs) in the syllables of bell imitations (Figure 3) leads to the insight that phonetics of the vowels in the imitations can be roughly explained by the spectral characteristics of the bell sounds. (The first components in the VV diphthongs are likely to correspond to the “beginning” dots in Figures 4 and 5, whereas the single vowels can probably be linked to the averages of the “beginnings” and “ends”, or some intermediate values.) For instance, the F2s of the large bells (Figure 4) are close to F2s of a in speech (Figure 7), and this results in the prevailing as for the large bells (Figure 3).

The same can be stated on the prevailing is for the small bells. Compare F2 for small bells (Figure 5) with F2 for i (Figure 7). Thus one can speculate that the usage of the “natural” F2s for recognition (as the cues for differentiation between “low-timbre” vs. “high-timbre” vowels) is relevant in this case. “F1s” of the bells show larger deviations from their counterparts in speech but they, possibly, play some supplementary role in the recognition of vowels, in the case discussed.
Imitations of bells

Figure 4. Change of the “formant frequencies” from the beginning to the end of the stroke of the large bell (Example 1).

Figure 5. Change of the “formant frequencies” from the beginning to the end of the stroke of the small bell (Example 2).

Figure 6. Change of the spectral centre of gravity from the beginning to the end of the strokes of large and small bells (Examples 1 and 2).
Actually, the obtained correspondence between the bell sizes and the vowels associated is not unexpected. It has been known that low/dark sounds tend to associate to large objects and high/bright sounds to small objects. This reflects one of the general propositions of linguistic sound symbolism (Hinton, Nichols & Ohala, 2006) which can be referred to as “frequency code” (Ohala, 2006), one of three linguistic “biological codes” (Gussenhoven, 2004, p. 71–95). As for the vowels, the parameter of vocal resonator most responsible for conveyance of size is F2 (Ohala, 2006, p. 335–336, 340–341). In our paper, we present the empirical evidence of the associations discussed for church bells. Not only are correspondences dark-large and bright-small exemplified, but also responsible F2s are evaluated and collated. This provides an explanation for the usage of certain vowels. Also the statistical strength of the rule (dark-large, bright-small) – i.e., its validity for different cases of interest – is evaluated.

**VV diphthongs**

The percentage of syllables containing vowel diphthongs shows considerably higher values in the case of Lithuanian traditional onomatopoeia of bells (O; Figure 8), in comparison with standard Lithuanian (L). (Here the data on various sizes of bells are pooled.) Moreover, the values obtained from the imitation experiment (1–4 in Figure 8, i.e., pooled for Examples 1–4) are even higher. It means that there is a tendency to sense phonetic change in the course of a bell stroke.

The vowel classes (u, o, a, e, é, i) can be grouped into phonetically relatively intense (o, a, e) and weak (u, é, i) vowels. That is, other conditions being equal (intensity of the voice source, effective relation between the fundamental and formant frequencies, etc.), the outputs of the vowels differ in intensity. Then we can group the vowel diphthongs into three classes characterized by decreasing (au,...), increasing (ie,...), or roughly constant (ui,...) intensity.
Figure 8 shows that, whereas usage of the VV with “decreasing intensity” prevails in standard Lithuanian, this prevalence is even greater in cases of bell imitations. The explanation seems to be very simple: intensity dynamics of a bell stroke is characterized by the decay curve (Figure 9), as well as intensity dynamics of many other sounds originating from the momentary (not continuous) excitation.

![Graph showing changes in phonetic intensity in VV diphthongs.](image)

**Figure 8.** Changes in phonetic intensity, in VV diphthongs (percentage of the syllables containing the corresponding diphthongs). See the text for the abbreviations and other details.

![SPL tracks of two first strokes of the small bell.](image)

**Figure 9.** SPL tracks of two first strokes of the small bell (Example 2). Time span 2.0 s, SPL range 20 dB.

![Graph showing changes in F2 in VV diphthongs.](image)

**Figure 10.** Changes in F2, in VV diphthongs (percentage of the syllables containing the corresponding diphthongs). See the text for the abbreviations.

Also, the changes in phonetic quality (in terms of F1 and F2) in VV evoked by bell strokes can originate from the corresponding spectral changes in the strokes (Figure 10). There is a prevalence of vowel diphthongs with increasing F2 (i.e., change from (more) back to (more) front vowels) in standard Lithuanian. However, this prevalence
is not as strong in the case of traditional bell onomatopoeia, whereas there is an opposite tendency (from front to back vowels) for the nonsense syllables evoked by the examples of bell sounds in the imitation experiment (Figure 10). This can be explained by the spectral changes in the bell strokes (Figures 4 and 5).11

VC diphthongs

One should stress that bell strokes evoke not only vowel diphthongs (VV), but also vowel-consonant diphthongs (VC; such as im, an) very frequently. It was found that VC diphthongs appear in 21% of the syllables in the traditional onomatopoeia of bells and in 46% of the syllables written down in the imitation experiment. The numbers for nasals (m and n as the second components in VC) are 13% and 45%, correspondingly.

Probably similar phenomena to those evoking VV diphthongs are at work: nasals are characterized by relatively intense bands of low frequencies (e.g., Kent & Read, 2002, p. 182-183), and this lowering is also present in the course of a bell stroke. In addition, the perception of nasality can be caused by another feature of the bell spectrum: its envelope contains some “dips” (Figure 11), which can work as antiformants common in the spectrum of nasals.12

![Figure 11. Spectrum of sound of the large bell (Example 1). The end of the first stroke is considered (time interval 300 ms before the succeeding stroke). Spectral range 0-2500Hz, SPL range 40 dB. Two suppositional low frequency “dips” are roughly marked. LPC spectrum envelope overlaid.](image)

Initial consonants in syllables

Mostly voiced plosives are found in the beginnings of the syllables imitating bell strokes (1-4 in Figure 12). As for the ratio of occurrences of voiced vs. voiceless plosives (not shown here), the prevalence of the voiced plosives is probably caused by
the continuance and dominance of the “tonal” components in the bell spectrum (i.e., the component of noise is negligible and there are no gaps of silence).

It should be noted that the percentages of syllables containing plosives were calculated in different ways for standard Lithuanian and for the cases of imitations of bells. For standard Lithuanian, the total number of certain plosives in the text was divided by the total number of syllables. Specifically, end plosives also were considered (not only initial plosives) because the algorithm of automatic separation of initial plosives would be too complicated. Manual counting would be too time consuming as the text is huge. For the imitations, only the initial plosives were considered and the procedure was carried out manually. This means that the values obtained for standard Lithuanian are overestimated, so the contrast between standard Lithuanian and the imitations is even larger than appears in Figure 12.

Quite interestingly, b and especially d are more frequent than g, as seen in the results of the imitation experiment (1-4 in Figure 12). One may speculate that this outcome is caused by relatively short attacks of the bell strokes which possibly evoke the plosives with early voice onset times. It is known that bilabial, dental, and alveolar plosives are characterized by earlier VOTs than velar plosives (Kent & Read, 2002, p. 150, 160). And in general, it is known that namely plosives produce the shortest attacks in CV compounds, in comparison with CV containing other consonants. It seems that this fact explains the prevalence of plosives as initial consonants in syllables imitating bell strokes.

![Figure 12. Some initial consonants in syllables. Abbreviations as in Figures 8 and 10.](image)

**Conclusions**

Not surprisingly, vocal imitations of instrumental sounds originate, to a large extent, from acoustical properties of the instrumental sounds. Imitations of bells is not an exception. Acoustics of church bell is quite different from acoustics of speech. Nevertheless bell strokes evoke at least fuzzy perception of speech syllables. Various connections between acoustics of these two types were discussed in the paper.
Two polar cases of the correspondence between the acoustics of bell and acoustics of speech could be considered, not to mention the intermediate cases. First, when there is rough correspondence between the absolute values of acoustical parameters (for instance, certain cases of the correspondence between formants). To some extent, it works, for example, in the perception of guitar sounds as something similar to speech sounds (Traube & Depalle, 2004). The second case probably is more characteristic: when there is correspondence between the relative values of acoustical parameters of contrasting sounds. It means, change of certain parameter of bell sound evokes the change of the same parameter of speech sound in the same direction, but the absolute values do not coincide. Seemingly, it is also the case of phonetics assigned to tabla (Patel & Iversen, 2003) or flute (Lavoie & Traube, 2009; from discussion) sounds.

Statistics of usage of different sounds and their combinations in standard language and in purely onomatopoeic imitations of bells (nonsense syllables) differs considerably. To be precise, certain speech sounds or their combinations are preferred in the imitations. Lithuanian traditional vocal imitations of bells (a layer of folklore), and the statistics of their phonetics present an intermediate case between standard Lithuanian and the imitations of bells by nonsense syllables. Understandably, it results from the mixture of purely onomatopoeic qualities and the qualities of lyrics in the traditional imitations.

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References


Lithuanians were the last pagans in Europe: Lithuania was formally Christianized at the end of the 14th century, and Christianity was established considerably later.
The bell sizes are not standardized. One can roughly estimate the size classes binding them to the pitches of strike tones ranging from about C4-E4 for the large bells to about C5-E5 for the small bells (see the examples in our experiment; Vilys, 2000).

Western part of Lithuania and East Prussia (present day Königsberg/Kaliningrad District) that was part of Germany for several centuries

mostly the largest archives of folklore and folk music at Lithuanian Institute of Literature and Folklore and at the Lithuanian Academy of Music and Theatre (in Vilnius).

The detailed explanation of the technique applied will be described in another paper.

It is worth mentioning that previously the experiment was carried out with another group consisting predominantly of respondents with East Slavonic origins (the conference version of the paper; Ambrazevičius & Balsienė, 2009). The two groups showed essentially the same results, with some minor, though interesting differences. The detailed cross-cultural comparison will be presented in another study.

generalized version of spectral centroid, briefly and simply, “a measure for how high the frequencies in a spectrum are on average” (from Manual of Praat)

To be precise, it should be noted that the listeners phonetically associated bell sounds rather than bell sizes. The distinction small/large is used in the paper mostly for the sake of simplicity, but actually here the issue of size is epiphenomenal. This problem can also be illustrated by the study of Traube and Depalle (2004): the differences in phonetic perception of guitar sounds (evoked due to varying plucking positions) had nothing to do with the size of the instrument. Thus, even though the frequency code is proposed to be equated to a “size code” (Gussenhoven, 2004, p. 81), some nuances regarding the audial and visual aspects of the code should not be overlooked; see also similar issues of “sounds vs tongues” (Ohala, 1996).

See also the spectrogram in Figure 1 and, for comparison, refer to Perrin’s et al (1983) measurements of decay times: they varied from 52 s (mode (2,0), hum) to only 2 s (mode (8,1), sixth).

For instance, normally F2-F1 is at least some 300 Hz (see, e.g., Figure 7; for a). If the envelope of spectrum shows thicker structure of crests and dips, this presumably can be perceptually considered as impact of additional antiformants resulting in the nasal quality (Figure 11).

Biographies

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