Dissonance/roughness and tonality perception in Lithuanian traditional Schwebungsdiaphonie

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Background in ethnomusicology. The term Schwebungsdiaphonie (‘beat diaphony’) refers to two-part musical (usually vocal) styles with a lot of dissonant (beating) intervals such as seconds. In contrast to Western tonal music, the dissonant sonorities in Schwebungsdiaphonie lie at the core of their tonal structures. These musical cultures, although not abundant, are found in different locations all over the world (Cazden, 1945; Brandl, 1989; Messner, 1989; etc.). Sutartinės are a Lithuanian type of Schwebungsdiaphonie (Račiūnaitė-Vyčienienė, 2002; Ambrazevičius & Wiśniewska, 2009).

Background in psychoacoustics. Roughness is considered either synonymous with sensory dissonance or its main component. It is caused by fast beating (amplitude modulations). Schwebungsdiaphonie singers adjust interval sizes to maximize sensory dissonance (Brandl, 1989; referring to the diaphony in the Balkans and elsewhere; Ambrazevičius, 2008a, referring to Lithuanian Sutartinės).

Aims. We aim to differentiate between roughness and sensory dissonance (as defined in psychoacoustic studies) and consider the case of Sutartinės in this context. A supplementary purpose is to discuss the phenomena of tonality perception in Sutartinės.

Main contribution. The psychoacoustic studies were overviewed and discrepancies between the concepts of roughness and sensory dissonance were noted. The experimental findings on the intervals corresponding to the maximum values of roughness / sensory dissonance were collated and significant disparities were found. It seems that, at least for a substantial frequency range, maximum roughness is associated with larger interval sizes than maximum sensory dissonance. Comparing these results with the findings of acoustical measurements of Sutartinė performances suggests that the ideal vocal “clash” in Sutartinės involves maximum roughness, but not maximum sensory dissonance. The tonal hierarchies in Sutartinės diverge substantially from Krumhansl’s tonal hierarchy profiles, anchoring on a central nucleus and dissipating towards more peripheral pitches. Nevertheless, some associations with the tension-relaxation patterns characteristic of Western tonal music are apparent.

Implications. Studies on sensory dissonance and roughness should define these notions more specifically and differentiate them. Findings may contribute to ethnomusicological courses on Sutartinės (and probably Schwebungsdiaphonie, in general).

Keywords: Sutartinės, Schwebungsdiaphonie, roughness, sensory dissonance, tonal hierarchies.

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Introduction: Dissonance/roughness in Schwebungsdiaphonie-cultures

Schwebungsdiaphonie means ‘beat diaphony’, i.e., the style of performance where dyads of parts form predominantly rough sonorities (or at least result in audible beats). The notion can be extended to music with more than two parts. Examples of Schwebungsdiaphonie are found in the Balkans, Indonesia, and elsewhere (Cazden, 1945; Brandl, 1989; Messner, 1989; Muszkalska, 2002; Vassilakis, 2005).

In sharp contrast to Western tonal music, in which consonant or smooth sonorities are preferred and dissonances resolve onto consonances, sonorities in Schwebungsdiaphonie-cultures are maximally dissonant or rough. The basic aesthetic standards and notions are somehow reversed. Strong (in terms of roughness) “clashes” of seconds are positively connoted.

In Schwebungsdiaphonie, timbre may be considered more important than pitch. The emphasis is on the quality of sonorities (timbre, in a broad sense) rather than the intervals themselves; the intervals can be considered epiphenomenal (e.g., Muszkalska’s 2002 examples of “appropriate mistuning” in Portuguese multipart singing, Cross’ 2003 notes on tara quality in campesino culture, Bolivia, studies on gamelan, such as Erickson, 1986).

Basics of Sutartinės

Principles of performance

Sutartinės (singular: Sutartinė) constitute an important part of Lithuanian polyphonic song lore. Many (but not all) Sutartinės can be regarded as a kind of Schwebungsdiaphonie. They are based on polyphonic and polyrhythmic patterns resulting from intertwining vocal parts. Mostly two voices perform simultaneously, creating sequences of chords that are mostly dissonant (from the viewpoint of Western music theory), namely, intervals of a second.

Figure 1 shows a typical example of a Sutartinė. The transcription is presented on a non-standard musical staff to avoid associations with the diatonic scale. The intervals between the neighboring scale notes are mostly slightly smaller than a tempered whole tone, so the intervals between the staff lines approximate neutral thirds (see the detailed examination below).

This Sutartinė is performed canonically by three singers in such a way that the two parts A and B sound simultaneously, except in the beginning when only one voice (part A) sounds. Thus mostly intervals of the second occur continuously between the two voices.
Figure 1. Simplified transcription of an example of Sutartinė. Top: A and B patterns sounding simultaneously. The petit notes show the most characteristic variants. Bottom: canonical structure of the performance in three voices; a single voice is composed of two consecutive patterns A and B depicted above.

There are also Sutartinės sung in two and four voices (performed by two and four singers) as well as some other peculiar types of Sutartinės. In most cases, Sutartinės are based on the second interval relations between the voices.

Sutartinės were performed mostly by groups of women who had extensive experience of singing together. The continuous tradition of Sutartinės vanished in the middle of the 20th century, however, and the reconstruction of this singing style is very popular nowadays among urban folk singers.

Intervals in dyads

Acoustical measurements of Sutartinės were presented in our previous studies (e.g., Ambrazevičius, 2008a; Ambrazevičius & Wiśniewska, 2009); here I summarize the relevant findings on scale and harmonic interval size. Mostly software Praat was used (also Speech Analyzer and Winccel, in the earliest studies); the pitches (as logf) were calculated from the frequencies of the partials in the spectra of the vocal dyads. Figure 2 shows the results for the example presented in Figure 1.

The results reveal a distinct equitonic structure of scale steps with roughly 180 cents in between. That means, two simultaneously sounding modi show two trichords displaced by 1.8 semitones and comprised of neutral thirds (sized appr. 3.6 semitones each). In the structure, the central bichord clearly stands out. The two steps are intoned very steadily in the course of the entire performance thus forming the nucleus of the scale. The marginal steps show greater freedom in intonation.
Figure 2. Histogram of pitches in Sutartinė ‘Myna…’ (Figure 1); all pitches in all parts. The bin is 20 cents.

An overall distribution of harmonic dyad intervals in 25 Sutartinės (based on 862 dyads) is shown in Figure 3.

Figure 3. Distribution of harmonic interval sizes in 25 Sutartinės.

The majority of the intervals are approximately a major second. The interval’s uncertainty or category width is quite large and it does not split into minor and major seconds. Note that seconds that are slightly smaller than the tempered whole tone (around 1.7 semitones) are most preferred.
Roughness versus dissonance

Psychoacoustic studies

In the psychoacoustic literature, notions of dissonance and roughness (as psychoacoustic dimensions) are sometimes distinguished, but they usually tend to be equated. It is generally believed that the two notions are merely two manifestations of the same phenomenon; “roughness” belongs to a somewhat “technical” domain of psychoacoustics, whereas “sensory dissonance”, if even comes from psychoacoustics, stands for somewhat “music-colored” attribute, being understandable for musicians.

The seminal study of Plomp and Levelt (1965) could serve as a typical example of the presumed interchangeability of the two notions. While the authors asked the subjects to judge intervals on the scale “consonant-dissonant” (or, in the case of incomprehension, they substituted the “consonant” with “beautiful” or “euphonious” instead; p. 553), they exploited both notions of dissonance and roughness unambiguously in their discourse. In many other studies, the questions presented to the participants are not revealed and the procedures of the experiments are not (or only faintly) detailed. Therefore, the subjective sonic qualities meant and evaluated in the experiments remain obscure.

Although roughness is not the only component of sensory dissonance. According to Fastl and Zwicker (2007, p. 245), sharpness is the most important constituent of sensory dissonance (the reciprocal of sensory pleasantness). Roughness and dissonance have even been found to correlate with different dimensions: Geer, Levelt, and Plomp (1962) found that roughness belongs to the dimension of fusion (including also the scales “more tones” and “active”), whereas dissonance-consonance belongs to the dimension of evaluation (or pleasantness; together with the scales “euphonious” and “beautiful”). Therefore, “care must be taken when instructing listeners to judge intervals. Some terms are largely synonymous (such as euphonious and pleasant), whereas other terms are not interchangeable (such as pleasant and fused) [or, we would add, such as dissonant and rough]” (Huron, undated). The confusion of sensory dissonance and roughness was also noted by Parncutt (2006, p. 202).

Moreover, several types of roughness can be distinguished; roughness may even be considered multidimensional (Hartmann, undated). One refers to a sequence of the beat rate dependent phenomena such as fluctuation strength, “finer and sharper” roughness, “coarser” roughness, R-roughness (α-roughness), “clattering” and “actual” roughness; sometimes these labels seem to be confused and used differently by different authors (e.g., Springer & Weber, 1994; Prünster, Fellner, Graf, & Mathelitsch, 2004).

Probably, the confusion between the dissonance, roughness, and its possible types explains why the results of experiments on the relationship between roughness/dissonance and interval size show significant discrepancies (Figure 4). Even though some of such results come from theoretical modeling, the authors usually claim that there is a satisfactory correspondence between the theory and experiment.
Some secondary reasons could be at work making the results of experiments different, yet they do not seem to have an important influence. For instance, a number of studies employ AM (amplitude modulated) sine tones, while others use sine tone pairs. Terhardt (1968, p. 219) claimed that the results do not differ significantly for the two cases, or at least that maximum roughness/dissonance occurs at the same interval size, regardless of the modulation frequency in the AM case or the frequency difference in the pure-tone pair case; Terhardt, 1974, p. 207–208; Vassilakis, 2001, p. 43).

The curves in the Figure 4 were composed based on the results from the following sources: Terhardt, 1968, Figure 5 in p. 219; Fastl & Zwicker, 2007, Figure 11.2 in p. 259 (similar results come from Aures, 1984, Figure 2.27 in p. 63); Leman, 2000, Figure 3 in p. DAFX-5; Rakowski, 1982; Sethares, 2005, p. 345-346 (also see Vassilakis, 2001, p. 195); and Hutchinson & Knopoff, 1978 (here their formula for critical bandwidth was used and the Plomp’s and Levelt’s 1/4 CBW-criterion for the maximum dissonance was applied).

The Terhardt’s, Fastl and Zwicker’s, and Leman’s curves were composed based on the interpolations of graphically presented results from the sources; a “smoothed line” option in MS Excel (based on third-order Bezier Spline) was used for the interpolations.
The rest of the curves were composed based on the formulas presented in the sources. Specifically, according to Rakowski, the frequency interval $\Delta f$ for maximum roughness approximates $2\sqrt{f_c}$ ($f_c$ stands for the central frequency). Sethares and Vassilakis use the following formula for dissonance (the part dependent of frequencies) derived as parameterization of Plomp and Levelt’s dissonance curves:

$$d = e^{-b_1(s_f - s_i)} - e^{-b_2(s_f - s_i)}$$

where

$$s = \frac{x^*}{s_1f_1 + s_2},$$

$$x^* = \ln \frac{b_1}{b_2},$$

$$b_1 = 3.5, \ b_2 = 5.75, \ s_1 = 0.0207, \ s_2 = 18.96, \ f_1 \text{ and } f_2 \text{ are frequencies of the sine tones (thus } f_c = (f_1 + f_2)/2). \text{ Therefore, maximum dissonance occurs for frequency interval }$$

$$\Delta f = \frac{s_1f_c + s_2}{1 + \frac{s_1}{2}}.$$

Hutchinson and Knopoff derived the following formula for the critical bandwidth:

$$CBW = 1.72f_c^{0.65}.$$

Provided the Plomp’s and Levelt’s 1/4 CBW-criterior for the maximum dissonance is applied,

$$\Delta f' = 0.43f_c^{0.65}.$$

A closer examination of Figure 4 reveals that roughness is typically associated with larger interval sizes, and that sensory dissonance is associated with narrower interval sizes. For instance, Terhardt in his experiment asked the subjects specifically to evaluate roughness (1968, p. 216), and the corresponding curve lies higher. Fastl and Zwicker also considered roughness, as did the model by Leman does.iii On the contrary, as already mentioned, the well-known relating of the maximum dissonance to 1/4 of critical bandwidth (Plomp & Levelt, 1965) refers specifically to dissonance but not to roughness.iv This notion transfers to Hutchinson and Knopoff, and also to Sethares and Vassilakis. The corresponding curves lie lower.

On the one hand, roughness is typically associated with the perceptual result of rapid fluctuation of the sound pressure envelope; it depends on both the modulation depth and the rate of beating (Fastl & Zwicker, 2007, p. 262), or, expressed more
subjectively, the “bumpiness of the [subjective] acoustic surface of a sound” (Parncutt, 2006, p. 202). On the other hand, sensory dissonance may depend on critical bandwidth, or the ability of the ear to separate simultaneous tones with nearby frequencies. Doubts remain about the relationship between the “bumpiness” of a sound’s amplitude envelope and critical bandwidth. From my purely subjective observations, the (sensory) “dissonance”, “unpleasantness”, or “annoyance” are related to “harshness” rather than “roughness”. One may therefore speculate that, for instance, a semitone in the middle of a piano keyboard sounds more harsh, whereas the whole tone seems to be more rough. Incidentally, the terms such as “harsh” or “turbid” occur episodically when describing non-euphonious, unpleasant, or dissonant sonorities (e.g., Plomp & Levelt, 1965, p. 554; Mashinter, 2006, p. 65, 66).

**Roughness in Sutartinės**

On the one hand, because of the first formant, the most intense partials in the spectra of singing voices are usually in the frequency range roughly from 400 to 800 Hz, in the case of Sutartinės (i.e., female voices). This corresponds to the second or third (or sometimes fourth) harmonic (Figure 5; here the background noise is quite pronounced because of poor technical quality of the old recording). On the other hand, as already discussed (specifically in relation to Figure 3), the intervals slightly narrower than the tempered whole tone are most preferred between fundamental frequencies in Sutartinės.

If we apply these values of frequencies to the graphs in Figure 4, one can presume that the singers were aiming for maximum roughness. In other words, they “clashed” their voices in the intervals that would most probably create the maximal sense of roughness. Therefore, the intervals in Sutartinės were perhaps based not on some pure musical qualities, but rather on the psychoacoustical phenomenon of roughness.

To be precise, it is known (and logically predicted) that the sensation of roughness depends severely on the fluctuation degree, which, in turn, in the case of a beating tone-pair, depends on the ratio of amplitudes of the partials under consideration. The maximum roughness is produced in the case of equal amplitudes (the equal amplitudes were assumed by default in the preceding discussion of the current paper). Roughness diminishes rapidly with the increasing ratio. The condition of maximum roughness therefore cannot be ideally satisfied. In a quite rapid performance, there are limited possibilities to coordinate the voices so that the amplitudes of the most intense partials were roughly equal. However, it seems that the singers adjusted the relationship between the harmonics of the voice and the resonances of the vocal tract to equalize the amplitudes as much as possible. Therefore, the differences in the amplitudes of the most beating partials did not exceed some five decibels, in the typical cases (Figure 5; the two typical instances are presented to show two cases of the most beating partials: (top) the second harmonics and (bottom) the fourth harmonics).
Figure 5. Two typical examples of Sutartinės spectra; from the beginning of ‘Myna…’. The vertical axis: SPL normalized to the most intense partial.

We should also stress that Sutartinės were performed in quite loud voices (e.g., Račiūnaitė-Vyčienė, 2002). Thus the singers heard each other in SPLs approximately from 70 to 90 dB. In contrast to other authors, Kameoka & Kuriyagawa (1969) stated that the interval corresponding to the maximum dissonance increases significantly with SPL. If one were to apply their findings, one could draw a conclusion that the intense sonorities in Sutartinės meet the condition of maximum dissonance (Ambrazevičius, 2008a). However, at the moment, further consideration of this issue is hardly possible because of two reasons. The first is the above-mentioned problem of obscurity of the notions: it is not fully clear if the Japanese subjects tested in the experiment really meant dissonance and not roughness or even something else when using the specific Japanese connotations in their evaluations (Kameoka & Kuriyagawa, 1969, p. 1452). Second, there are certain doubts
concerning the sufficient precision of Kameoka’s & Kuriyagawa’s results (Mashinter, 2006; etc.).

At any rate, it seems that Sutartinės singers were referring specifically to roughness when they described sonorities as “clashing” (clanging, warbling; but not “cutting” which would point to the sensory dissonance and narrower intervals). The “strong clash” was considered by the singers as an essential quality and marker of a congenial performance.

Importantly, the noun Sutartinė derives from the verb sutarti which means ‘to agree’, ‘to be in concord’ (‘to live in concord’, ‘to sing in concord’, and so on); in other words, ‘to sing in consonance’. Nowadays the word Sutartinė is sometimes even applied to signify a perfect, harmonious performance in general, no matter the kind of the performance.

To summarize, the peculiar interval structures characteristic of Lithuanian Schwebungsdiaphonie (based on the intervals slightly narrower than tempered major second; with quite a wide range of variations) can be linked to the psychoacoustic experiments on roughness. However, in the case of the Schwebungsdiaphonie, roughness obtains a positive connotation.

Some performers of Schwebungsdiaphonie compare its sound with bells (Brandl, 1989, p. 59; Račiūnaitė-Vyčinienė, 2002). This comparison may be based on similar psychoacoustic qualities (i.e. close partials, beats, attacks, and frequency range). It is also interesting that the quality of “bell tones” is found to be important and desirable even in the distant style of barbershop singing characterized by an abundance of certain rough sonorities that create the “heaven of the seventh” (i.e. the interval of seventh gets strong positive connotations; Averill, 1999). The similar relations of the phenomena (roughness – “bell quality” – positive connotations) characteristic of quite distant musics possibly point to the similar trends in the specific music cognition.

**Tonality perception in Sutartinės**

The sample presented in Figure 1 was chosen for the probe tone test, similar to the one developed and applied by Krumhansl (for instance, Krumhansl, 1990). The sound recordings were presented to two groups of subjects: the first group consisted of contemporary performers of Sutartinės; the second group was comprised of students from two Lithuanian universities. The results averaged across the subjects in Group 1 are presented in Figure 5. (The results for Group 2 are essentially similar and are not presented here; see Ambrazevičius & Wiśniewska, 2009, for the detailed description of the experiment and its results.)
Figure 6. Tonal profile of Sutartinė ‘Myna...’ (Figure 1: scale notes 2-7) derived from the probe tone test (Group 1). Additionally, lower (1) and higher (8) notes absent in the scale of the sample are included. Standard deviations (s) of the ratings among the respondents are also shown.

Figure 6 proves that there are hierarchical differences between the different scale notes in the Sutartinė. The two central pitches (4th and 5th in Figure 6) are the most salient (in terms of cognitive saliencies of the pitch classes), whereas the salience diminishes gradually when moving towards the marginal pitches. Quite interestingly, the central and marginal pitches show the least scatter of estimations while the scatter is considerably larger for the rest of the pitches. This means that cognitive categorizing is at work: the boundaries between the “fit” and “no fit” are estimated relatively indefinitely. Obviously, the cognitive basis of this structure is completely different from that of the major-minor system described by Krumhansl (1990, etc.) and others. The subjects (Group 1) give approximately the same ratings for the two central pitches. One can say that they feel the “double tonic” constituted of the two most prominent pitches of the intertwining vocal parts.

It was shown that the peculiar scale structure is also reflected in the acoustical stability of intonation (i.e., closeness of intonations of the same scale degree in different occurrences): the two central pitches are intoned most precisely, as well as the interval between them (Ambrazevičius, 2008a). When moving to the marginal pitches, the stability of intonation decreases. By the way, this could be observed already in Figure 2. The principle of maximum roughness is followed more consistently when performing the central interval, whereas it is not that important when performing the marginal intervals: the standard deviations of the marginal intervals are larger.

The sequential movements of the vocal dyads create the impression of melodic contours that are akin, in a general sense, to the melodic contours found in monophony. Indeed, in most cases, the patterns can be considered as successive movements in “double melodies”, i.e., lines made of two voices, an interval of a
second apart (see, for example, Figure 1). When listening to Sutartinės performances, one’s attention tends to concentrate not on the separate voices, but rather on their merged results appearing as “melodic lines”. There are no big leaps in the lines; they are made mostly of succeeding steps. Thus the element of linear thinking in Sutartinės is revealed.

Concerning the horizontal (time) component, the ordinary (for Western tonal music) resolution of dissonance into consonance is not observed. However, the tension-resolution patterns analogous in deep structure to the patterns known in Western music could be envisaged. In other words, some similarities in the general (universal?) “logic” could be possibly stated. For instance, in 8-dyad patterns, the contours tend to rise in the first half and then fall in the second half (Ambrazevičius, 2008a). Thus certain correspondences to the harmonic movements in the circle of fifths in tonal music can be envisaged: the contour “modulates” from the tonal centre (“Tonic”) up (to “Subdominant”), then returns to the tonal center, and finally moves to “Dominant”, thus leaving the “unresolved cadenza” and preparing the next repetition of the pattern. In other words, the movements of (“dissonant”) sonorities from scale nucleus towards scale margins and back correspond to the T-S-T-D-T (or similar) sequence in Western music.

Conclusions

The intervals in Sutartinės performances are based on the psychoacoustic phenomenon of roughness (perhaps even maximum roughness). It should be stated that here specifically roughness and not sensory dissonance is meant; it could be that this is not necessarily the case with some other Schwebungsdiaphonie-cultures. This results in the peculiar scale structures deviating considerably from the twelve-tone equal temperament. The rough quality of the sonorities obtains positive connotations, i.e., in a broad sense, these sonorities are considered as “consonances”. The fact that intervals in Sutartinės are determined by the criterion of maximum roughness means that learned scales play a weaker role (if they play a role at all) than in western tonal music.

The requirement of maximum roughness is not evenly applied to the different pitches and intervals: most likely, it is crucial for the central scale pitches and the central intervals, while it is less important for the marginal pitches and intervals. This results in a peculiar scale structure wherein the scale is centered on a “double tonic” and “dissipates” towards its margins (some modifications of the scheme are possible). So the tonal profiles for Sutartinės are totally different from the profiles characteristic of the ordinary 12-tone chromatic scale: the shapes are not undulating but rather spiked at a tonal nucleus.

Finally, the present study is evidence that roughness is universally perceived but its aesthetic evaluation can be remarkably different in different cultural contexts. That is consistent with the assumption (presumably widespread, e.g. Eberlein, 1994) that
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roughness strongly influenced the harmonic vocabulary of early vocal polyphony e.g. in the Catholic church.64

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References


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1 The digitized version of the old recording (from 1930s) is reissued in Račiūnaitė-Vyčiniénė, 1998.

2 There are more than 1 000 published transcriptions of *Sutartinės*, but only several dozens of the sound recordings remain from the first half of the 20th century. At the moment of the analysis discussed (2008), only 25 recordings were available. All of them were examined.

3 Leman, like many of other authors, equates sensory dissonance to roughness: “Following v. Helmholtz, many researchers have used the term *sensory dissonance* when speaking about tone relationships but it is nowadays more appropriate to use the term *roughness*” (Leman, 2000, p. DAFX-1). In his model, nevertheless, basically findings of other studies on roughness (or strategies attributed to the modelling of roughness) are applied.

4 Leman notices the incorrectness of the oversimplified $1/4$-formula even if based on the original experimental results of Plomp & Levelt (Leman, 2000, p. DAFX-2). However, even with the revised formula, the resulting curves would not get much closer to the roughness-curves.

5 Vassilakis gives power of $-3.11$ to which $(1+\text{ratio})$ should be raised (2001, p. 197). Quite large values for the exponent are also presented in other studies, more directly connected to roughness evaluations.

6 The last paragraph is proposed by Richard Parncutt.

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**Biography**

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