Psychoacoustic Aspects of Violin Sound Quality and its Spectral Relations

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The term 'sound quality' expresses timbre, enumeration of sound properties, or sound evaluation. Sound quality assessment depends on the evaluator and evaluation purpose. Psychoacoustics studies selected aspects of sound quality in a chosen sound and listener context. An experiment establishing sound quality preference and its spontaneous word description on five violin tones H3, F#4, C5, G5 a D6 is described. Connections of sound quality preferences to sound context, frequencies of occurrence of descriptive words, and spectral features of the sound are discussed. Common properties of stationary spectra of a high quality violin tone are formulated: a sufficient level of the fundamental; deep and narrow notches and well pronounced and filled elevations in specified frequency regions; and a balanced consecutive decrease of levels of harmonics across elevation bands.

SOUND QUALITY AND PSYCHOACOUSTICS

The term 'sound quality' can represent a common property of sound (timbre), enumeration of sound properties (distinctive features) or aesthetic evaluation of sound (preference). The listener, musician, and instrument maker perceive quality of the sound of a musical instrument differently. The complete set of features of musical instrument sound quality consist of: dynamic properties; players instrument control; timbre aspects of individual tones and their balance in the whole dynamic range and diapason; possibilities to modifying the sound and achieving the required sound impression.

The goal of psychoacoustics is to ascertain the properties of the interaction of sound and human consciousness and express its causal relations. Psychoacoustic research may focus on defined sound quality aspects and a specific sound context. The goal of one experiment carried out in our laboratory was to study sound quality as a set of timbral properties in words and quality evaluation .

EXPERIMENT

The violin sound quality was studied on recordings of tones H3, F#4, C5, G5, and D6 of eleven instruments of various qualities recorded in an anechoic room and played *détaché*, *naturale,* non-vibrato, and *mezzoforte*. The duration of all tones and their transients and transient shapes were unified [1]. A pair test with headphones was administrated with ten listeners. Perceived sound quality preferences and spontaneous word descriptions of timbre differences for each pair of sounds were registered. Using this data, individual and group preferences and later individual and group ranks in perceived sound quality were calculated. Internal consistency of individual preference judgements and concordance of individual ranks in the group of judges were established in all five studied tones. Correlations between sound quality ranks and frequencies of occurrence of individual words were also calculated. Amplitude spectrum, SPL in individual harmonics, and spectral center of gravity were calculated from quasi-stationary part of signals [1]. These spectral properties together with word descriptions and determined quality preferences were used to interpret the results.

RESULTS AND DISCUSSION

Only words with an overall frequency of occurrence of at least ten were evaluated. This represents 65 words for the H3 tone, 64 for F#4, 58 for C5, 64 for G5 and 65 for D6 tone. Correlations of occurrence of selected words with sound quality evaluation rank are found in Table 1. These twenty words belong to the thirty most frequently used in all five tones. The words *clear*, *voiced*, *damped*, *unvoiced* have highly significant correlation only in the G5 tone; this implies that this tone sound quality preference was based on different sound properties than other tones.

It is possible to observe a division of tested tones in two groups – H3, F#4, C5 and G5, D6 – based on the frequency of occurence of the words *dark* and *clear* (Table 2). The words *voiced*, *dumped* and *rustle* further differentiate G5 and D6 tones. The *rustle* in the highest tested tone (D6) is described in [2], and is caused by noise components originating in the band from 230 to 800 Hz.

Table 1. Correlations between sound quality ranks and frequency occurrence of words used for timbre description. Significance: bold $\alpha \leq 0.01$, normal $\alpha \leq 0.05$, italics $\alpha \leq 0.1$.

	H3	F#4	C5	G5	D6
balanced (vyrovnaný)	.67	*.52*	**.81**	.62	**.82**
clear (jasný)	–	–	–	**.82**	–
dark (tmavý)	**.86**	**.78**	*.57*	–	–
delicate (jemný)	.73	*.57*	**.88**	–	**.85**
full (plný)	**.80**	**.76**	**.91**	**.86**	–
pure (čistý)	.67	*.60*	–	.63	*.55*
round (kulatý)	**.83**	**.83**	.70	–	**.79**
smooth (hladký)	**.78**	**.77**	**.88**	–	**.79**
soft (měkký)	.65	**.75**	.69	–	**.78**
voiced (znělý)	–	–	–	**.80**	–
wide (široký)	–	.64	.70	**.75**	–
bleaty (mečivý)	**-.86**	*-.57*	**-.75**	–	–
damped (přidušený)	–	–	–	**-.76**	–
metallic (kovový)	**-.74**	-.73	**-.77**	–	-.72
narrow (úzký)	**-.79**	-.70	**-.87**	**-.90**	–
penetrating (pronikavý)	**-.84**	-.73	-.67	–	**-.88**
rustle (šustivý)	-.62	-.61	-.66	–	-.62
sharp (ostrý)	-.72	–	-.63	–	**-.75**
tinny (plechový)	**-.77**	**-.75**	**-.83**	–	**-.86**
unvoiced (neznělý)	–	–	–	**-.78**	–

Interesting correlations between sound quality ranks and some spectral characteristics are found in Table 3, where the G5 note is again exclusive. Comparing spectral envelopes of different quality sounds with the envelope of the highest quality sound, and comparing the envelope of the best tone in all five tested pitches enabled formulation of a hypothesis on the spectral shape of a high-quality violin tone [1]: The harmonic spectrum of a high-quality violin tone has a sufficient level of the fundamental; its envelope is characterized with deep and narrow notches N0-N4 and wide, well-pronounced and filled elevation bands E1-E4 in frequency regions given in Figure 1; and it has balanced consecutive decrease of levels of harmonics across elevation bands.

A steeper decrease of the spectral envelope in the H3, F#4, and C5 tones versus G5 and D6 (Figure 1) agrees with frequencies of use of the words *dark* and *clear* in the description of sound properties (Table 2). With increasing pitch it becomes more frequent that no harmonic falls into the notch, and the spectrum envelope of a high-quality tone fills and smoothes out. This may be the probable reason for the connection of quality evaluation in the G5 note with different words which describe other percepts induced through other spectral envelope properties.

Subjective evaluation of the quality of violin sounds depends on the number of spectral properties, which listeners describe in appropriate and different words. Spectral properties and their descriptive words can feature in various combinations and to different degrees consistently with listened sound context.

Table 2. Contrasts in ranks of overall frequency occurrence of selected words in individual tones, high ranks are bold.

	H3	F#4	C5	G5	D6
sharp (ostrý)	**2**	**1**	**1**	**1**	**1**
dark (tmavý)	**1**	**2**	**2**	10	11
clear (jasný)	15	10	8	**3**	**4**
narrow (úzký)	**6**	**3**	**4**	**2**	**3**
voiced (znělý)	16	11	20	**5**	13
damped (přidušený)	26	23	13	**6**	18
rustle (šustivý)	14	12	30	18	**6**

Table 3. Correlations between sound quality ranks and spectral characteristics. Significance see Table 1.

	H3	F#4	C5	G5	D6
Level of the 1st harmonic	*.55*	*.57*	**.82**	**.79**	*.52*
Spectral center of gravity	**-.80**	**-.77**	-.62	–	-.63

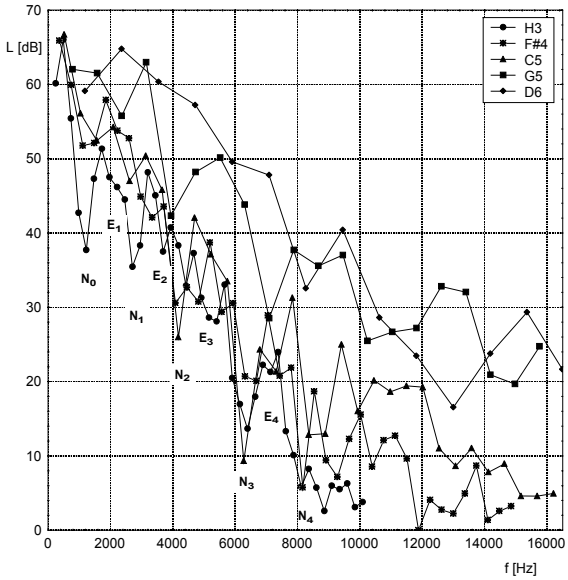

FIGURE 1. Harmonic spectra of the highest sound quality violin tones and positions of notches (Ni) and elevations (Ei).

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